A NEW COURSE IN TECHNICAL DRAWING

By the same author ;

EXAMPLES IN TECHNICAL DRAWING

EXAMINATION PAPERS IN TECHNICAL DRAWING

A NEW COURSE
IN
TECHNICAL DRAWING

PART TWO

by

D. MILLER, B.Sc., A.M.I.E.E.

THE HOUSE OF GRANT LTD
GLASGOW LONDON TORONTO

PREFACE

This New Course in Technical Drawing continues as a text book based on an applied knowledge of plane and solid geometry. So far as schools and early student training are concerned, the aim is to provide an interesting approach to professional practice. The geometrical solids can be recognised in the component parts of machinery and building details, while applications of plane geometry arise in surveying and construction. It is not desirable to continue too far towards an output of two dimensional drawings, showing different views of machine parts or assemblies, merely by rigid application of the conventional rules of projection, unless the pupil recognises that Technical Drawing has evolved from, and in practice is closely related to, the geometry and mathematics of the classroom. Ample scope is allowed for the teacher to introduce appropriate "technical" exercises of his own composition or from other sources.

Naturally, use will be made of technical vocabulary in the course of teaching, and it is important that the pupil should learn, within limits, the accurate usage of unfamiliar words in this "language" of Technical Drawing.

Acknowledgment is made to Messrs. Ferranti Ltd., Edinburgh, for the use of material from their technical literature in connection with Co-ordinate Drawing as used in their Computer Control System of machine tools; to The Nuffield Organisation, Oxford, for the illustration used in connection with "Exploded" drawing; and for facilities provided by Messrs. Dickson & Mann Ltd., Armadale and The North British Steel Foundry Ltd., Bathgate.

My thanks are due to H. H. Vaughan, B.Sc., M.I.Mech.E., for valuable suggestions and for reading through the final proofs of the book.

March, 1959. D.M.

CONTENTS

PART TWO

CHAPTER I

RATIO — SIMILAR FIGURES — PROPORTIONALS — REGULAR POLYGONS — EQUIVALENT AREAS — DIVISION INTO EQUAL AREAS — LOCI — LOCI OF MECHANISMS

DEFINITIONS

RATIO : If **A** and **B** are two magnitudes of the same kind (say both lengths or areas), and if **A** contains "**a**" units and **B** contains "**b**" units, then $\frac{\mathbf{a}}{\mathbf{b}}$ is called the ratio of **A** to **B** and is the relationship which one bears to the other in respect of quantity.

PROPORTION OR PROPORTIONALS : If the ratio of **a** to **b** equals the ratio of **c** to **d**, the four magnitudes **a**, **b**, **c**, **d** are said to be in proportion or proportionals. The relationship is written :

$$\frac{\mathbf{a}}{\mathbf{b}} = \frac{\mathbf{c}}{\mathbf{d}} \text{ or } \mathbf{a} : \mathbf{b} :: \mathbf{c} : \mathbf{d}$$

and is expressed as "**a** is to **b** as **c** is to **d**".

a and **d** are called the *extremes* and **b** and **c** are called the *means* of the proportion. The extremes and the means multiplied together are equal, e.g., if **a** = 2″, **b** = 3″, **c** = 4″, **d** = 6″ then :

$$\frac{\mathbf{a}}{\mathbf{b}} = \frac{\mathbf{c}}{\mathbf{d}} \text{ or } \mathbf{a} : \mathbf{b} :: \mathbf{c} : \mathbf{d} \text{ or } 2 : 3 :: 4 : 6.$$

and $\mathbf{a} \times \mathbf{d} = \mathbf{b} \times \mathbf{c}$ or $2 \times 6 = 3 \times 4$

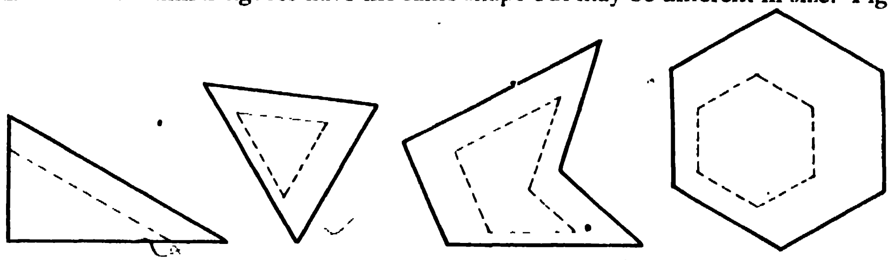
The *fourth* magnitude **d** is said to be a *fourth proportional* to the other three. Applied to geometry, this is the same as saying that the rectangle with sides 2″ and 6″ is equal in area to the rectangle with sides 3″ and 4″

MEAN PROPORTIONAL : When the third quantity of a proportion is in the same ratio to the second as the second is to the first, the quantities are said to be in *continued proportion* or in *geometrical progression*, e.g., if **a** = 2″, **b** = 4″, **c** = 8″ then:

$$\frac{\mathbf{a}}{\mathbf{b}} = \frac{\mathbf{b}}{\mathbf{c}} \text{ or } \mathbf{ac} = \mathbf{b}^2 \text{ or } 2 \times 8 = 4^2$$

Here **b** is called a *mean proportional*, or *geometric mean*, between **a** and **c** and **c** is called a *third proportional* to **a** and **b**.

SIMILARITY : Similar figures have the same shape but may be different in size. Fig. 1.



SIMILAR FIGURES Fig. 1

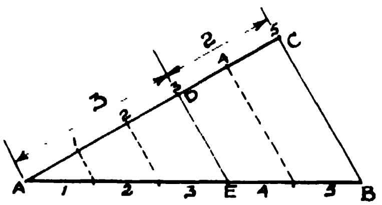


Fig. 2

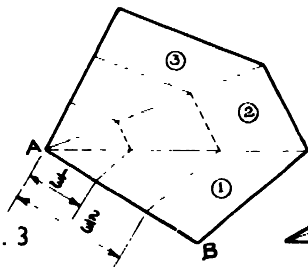


Fig. 3

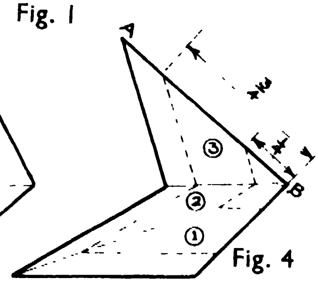


Fig. 4

A figure which is bounded by straight lines is called a *rectilineal figure* ; the circle is not such a figure. Rectilineal figures are said to be *equiangular* when their corresponding angles are equal and if, in addition, their corresponding sides are proportional the rectilineal figures are said to be *similar*. Therefore two conditions are necessary for similarity among figures (1) *the figures must be equiangular* and (2) *their corresponding sides must be proportional*. Circles, squares and regular polygons (having the same number of sides) are examples of similar figures.

This theorem is the basis of the construction used to divide a straight line into a given number of equal parts (Exercise 23, page 84, Vol 1). In triangle **ABC** (Fig. 2) **DE** is drawn parallel to **CB**. The point **D** divides **AC** in the ratio 3 : 2. As **AE** is also divided equally into 3 parts and **EB** into 2 equal parts, the whole line **AB** will contain 5 equal parts and :

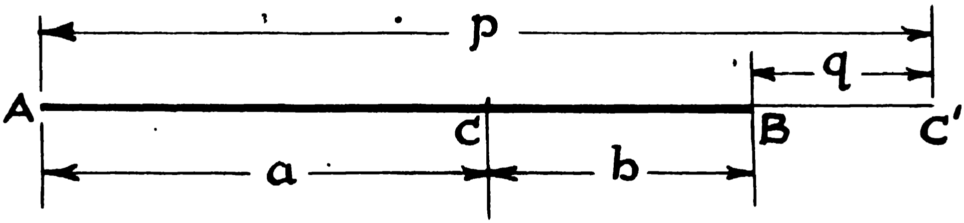
$$\mathbf{AD} : \mathbf{DC} = 3 : 2 \text{ and } \mathbf{AE} : \mathbf{EB} = 3 : 2$$

$$\therefore\ \mathbf{AE} : \mathbf{EB} = \mathbf{AD} : \mathbf{DC}$$

The theorem also provides for a convenient construction in the solution of problems on the reduction and enlargement of similar figures. **AB** (Figs. 3 and 4) is one of the sides of a polygon, consisting of three triangles; it will be seen that the foregoing construction (Fig 2), employing the property of proportionals, can be used to obtain polygons (shown by broken lines) which are similar and have their lineal dimensions proportional.

PROPORTIONALS

The division of a straight line in a given ratio.



If **C** is a point in a straight line **AB** then it is divided internally at **C** in the ratio **a** : **b** if **AC** : **CB** = **a** : **b** and externally at **C′** in the ratio **p** : **q** if **AC′** : **BC′** = **p** : **q**.

To divide a line AB (say $3\frac{7}{8}''$ long) into three parts in the proportion of 2 : 3 : 4, Fig. 5.

Set off on **AC** nine (2 + 3 + 4) equal parts.

Join **CB**

From the second part at **D** draw **DF** parallel to **CB**.

From the fifth part at **E** draw **EG** parallel to **CB**.

The given line **AB** is divided at **F** and **G** so that **AF** : **FG** : **GB** = 2 : 3 : 4.

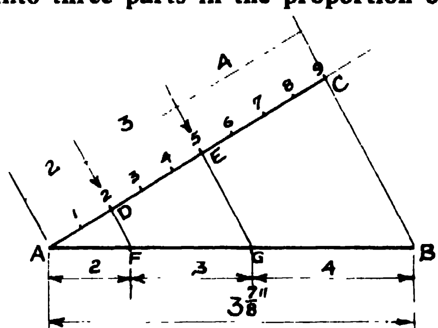


Fig. 5

To divide a line AB (say $4\frac{1}{2}''$ long) into two parts in the proportion of $2\frac{1}{2} : 3\frac{3}{4}$ Fig. 6.

Set off on **BC** seven ($2\frac{1}{2} + 3\frac{3}{4} = 6\frac{1}{4}$ with seven as next whole number) equal parts.

D is $2\frac{1}{2}$ parts from **B** and **E** is $3\frac{3}{4}$ parts from **D**.

Join **EA** and draw **DF** parallel to **EA**.

The given line **AB** is divided at **F** so that **FB** : **FA** as $2\frac{1}{2} : 3\frac{3}{4}$.

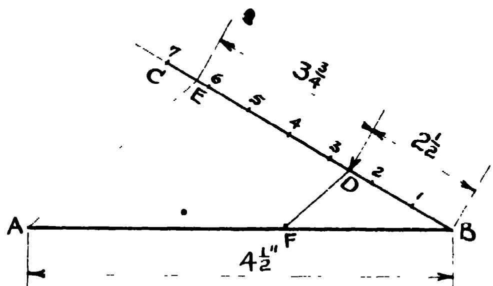


Fig. 6

To find a *third proportional* to two given straight lines, Fig. 7.

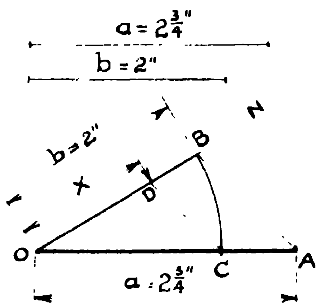


Fig. 7

P

Let **a** ($2\frac{3}{4}''$) and **b** ($2''$) be the given lines; to find a line **X** so that **a** : **b** : : **b** : **X**.

Draw two straight lines **OP** and **ON** (any lengths) making an angle with each other.

On **OP** set off **OA** = **a** and on **ON** set off **OB** = **b**.

With **O** as centre and **OB** as radius describe an arc cutting **OP** in **C**.

Join **BA** and draw **DC** parallel to **BA**.

OD is the required third proportional **X**.

(The line **b** is a *mean proportional* of **a** and **x**.)

To find a *fourth proportional* to three given straight lines, Fig. 8.

Let **a** ($2''$), **b** ($1\frac{1}{2}''$) and **c** ($2\frac{1}{2}''$) be the given lines; to find a line **X** so that **a** : **b** : : **c** : **x**.

Draw two straight lines **OP** and **ON** (any lengths) making an angle with each other.

On **ON** set off **OA** = **a**, **AB** = **b** and on **OP** set off **OC** = **c**.

Join **AC** and through **B** draw **BD** parallel to **AC**.

CD is the required *fourth proportional* **X**.

P

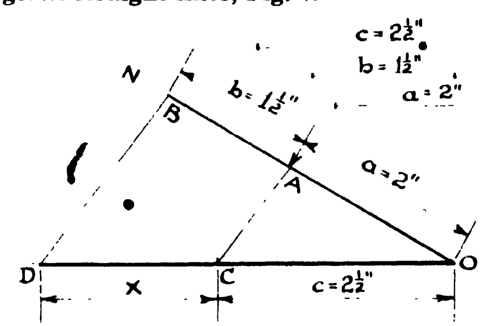


Fig. 8

To find a *mean proportional* to two given straight lines, Fig. 9.

Let **a** ($3\frac{1}{4}''$) and **b** ($\frac{3}{4}''$) be the given lines; to find a *mean proportional* to **a** and **b**.

Draw **AP** (any length) and on it set off **AB** = **a** and **BC** = **b**.

Describe a semi-circle on **AC** and erect a perpendicular **BD** meeting the semi-circle in **D**.

BD is the required *mean proportional*. Measure the length of **BD**.

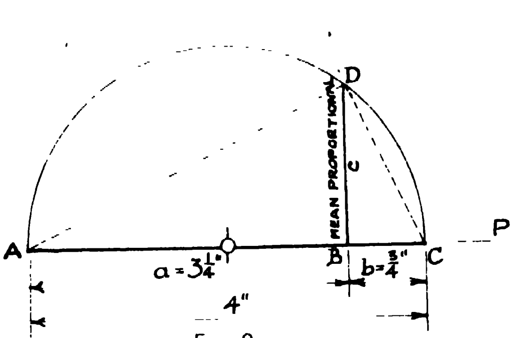


Fig. 9

Note: Triangle **ADC** is right angled at **D** (angle in a semi-circle) therefore triangles **ABD** and **CBD** are similar.

AB : **BD** :: **BD** : **BC**

BD is the *mean proportional* to **AB** and **BC**

a b c^2

REGULAR POLYGONS

To construct a regular polygon in a given circle, Fig. 10.

(The following method is approximate but is near enough for present requirements.)

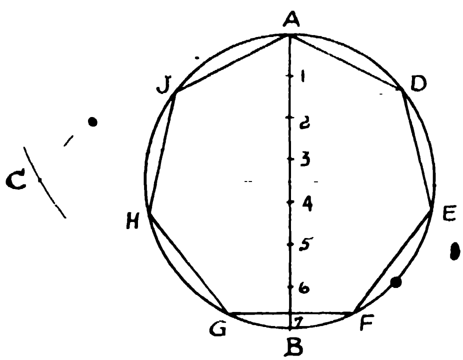


Fig. 10

Let the polygon be a *heptagon* (seven sides) ~~to be~~ inscribed in a circle of 3″ diam.

Draw a diameter **AB** and divide it into seven equal parts (the required number of sides in the polygon)

With **A** and **B** as centres and radius **AB** describe arcs cutting at **C**

Draw **C2** (through the second division) meeting the circle in **D**

The construction for DC must be drawn through the **second** *division in all cases*

Join **AD**, which will be a chord and is used to divide the circle into seven equal parts.

ADEFGHJA is the required heptagon

To construct a regular polygon of given length of side, Fig. 11.

Let the polygon be a *pentagon* (*five sides*) and **AB** the given side.

Draw **AB** (2″) and produce to **C**.

With **B** as centre and any radius, describe a semi-circle starting on **BC** and divide it into five equal parts (the required number of sides in the polygon).

Draw **B2**, through the second division on the semi-circle, and make **BD** equal to **BA**.

The construction for **B2** *must be drawn through the* **second** *division in all cases.*

Bisect **BA** and **BD** intersecting at **O** which is the centre of the polygon.

With **O** as centre and radius **OA**, or **OB**, describe a circle.

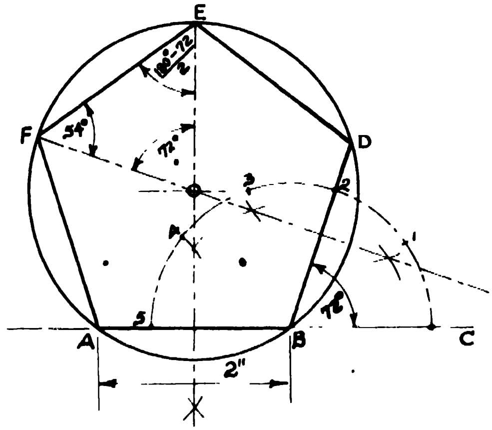


Fig. 11

The chord AB is used to divide the circle into five equal parts. **ABDEFA** is the required pentagon and the angle at the centre is $\frac{360°}{5} = 72°$.

ALTERNATIVE CONSTRUCTION USING BASE ANGLES Fig. 12

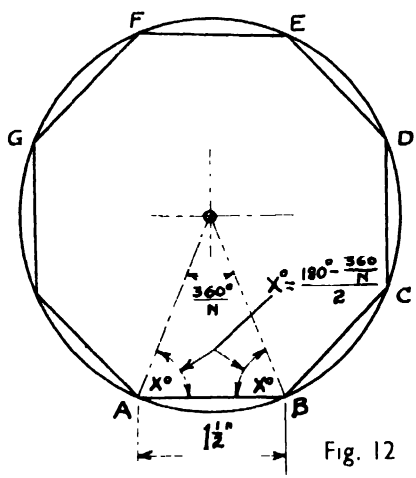


Fig. 12

Let **N** be the number of sides in the polygon and **AB** ($1\frac{1}{2}$″) the length of one side.

Set off on **AB** the base angles **X** $= \left(\frac{180° - \frac{360}{N}}{2}\right)$ so that **AO** **BO** form the isosceles triangle **AOB**.

With centre **O** and radius **OA** or **OB** describe a circle.

The chord **AB** is used to divide the circle into **N** equal parts.

Fig. 12 shows the construction for a regular octagon where the angle at the centre is 45° and each of the base angles is $67\frac{1}{2}$°.

EQUIVALENT AREAS

The area of a plane figure is the amount of surface which is contained by the boundary lines or perimeter of the figure.

To construct a rectangle equal in area to any given parallelogram, Fig. 13.

Let **ABCD** be the given parallelogram.

Produce **CD** in the direction **F** and on **AB** construct a rectangle **ABEF** (which is also a parallelogram).

Area **ABEF** Area **ABCD**.

Parallelograms on the same base (or equal bases) and between the same parallels are equal in area.

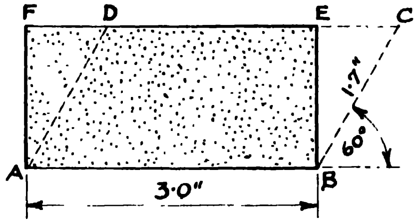


Fig. 13

To construct an isosceles triangle having an area equal to half that of a given rectangle, Fig. 14.

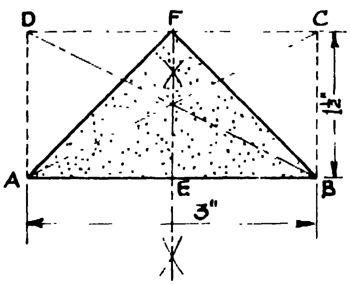


Fig. 14

Let **ABCD** be the given rectangle.

Bisect **AB** in the point **E** and draw **EF** perpendicular to **AB**.

Join **FA** and **FB**.

ABF is the required triangle. Insert the altitude and calculate the area of the triangle.

Note : The diagonals **AC** and **BD** divide the rectangle into two triangles each equal in area to half that of the rectangle. **AB** is a common base for these triangles and also that of the required triangle **ABF**.

Triangles on the same base (or equal bases) and between the same parallels are equal in area.

To construct a rectangle equal in area to a given triangle, Fig. 15.

Let **ABC** be the given triangle.

At **A** and **B** erect **AD** and **BE** perpendiculars to **AB**

Draw **CF** perpendicular to **AB** (or **AB** may have to be produced) giving the altitude of the triangle **ABC**

Bisect **CF** in **G**.

Through **G** draw **HGJ** parallel to **AB** meeting **AD** and **BE** in the points **H** and **J**.

ABJH is the required rectangle.

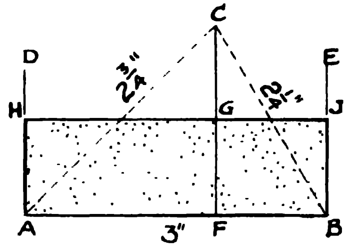


Fig 15

Note *Area of a triangle is base × half perpendicular height*

Area of rectangle is length × breadth = AB × ½CF = AB × FG

To construct a square equal in area to a given rectangle, Fig. 16.

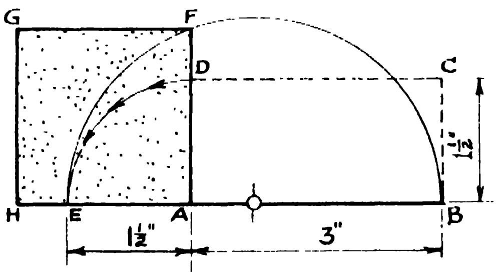


Fig. 16

Let **ABCD** be the given rectangle

Produce **BA** to **E** so that **AE** = **AD** (side of rectangle).

Find the mean proportional **AF** of **BA** and **AE** (sides containing the rectangle) by the method shown in Fig. 9

AF is a side of the required square **AFGH**.

Calculate the area of the square and compare it with that of the rectangle.

To construct a rectangle equal in area to a given square (2¼" side), one side of the rectangle to be 1½".

This construction, which involves the use of the mean proportional, is the converse of the previous problem. After a careful study of it, the pupil should be able to carry it out without further explanation.

Show, by means of broken lines, two other rectangles equal in area to the given square and insert the lengths and breadths of these rectangles

A construction similar to Fig. 16 can be used to obtain a square which will contain a given number of square inches (say 8), Fig. 17.

ABCD is a rectangle (4″ × 2″ = 8 sq. ins.).

Find the mean proportional **BF** of **AB** and **BE** (the sides of the rectangle).

BF ($\sqrt{8}$) is the length of the side of the required square **BFGH**. Insert this length on your drawing.

Note: Redraw this construction for 6 square units making one side of the rectangle $1\frac{1}{2}$″. Measure the side of the square; can you discover that this construction gives the graphical method for finding the square root of a number (6 in this case)?

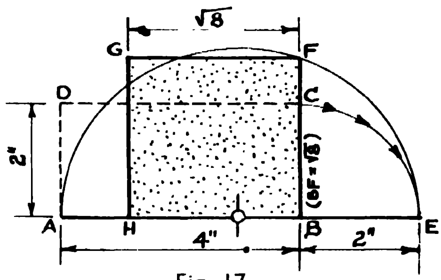


Fig. 17

Calculate the area of the rectangle and compare it with that of the square.

To construct a square equal in area to a given triangle, Fig. 18.

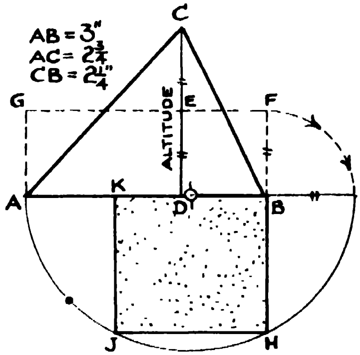


Fig. 18

Let **ABC** be the given triangle with **CD** as the altitude.

Bisect **CD** in **E**.

Through **E** draw **FG**, parallel to, **BA** meeting the perpendiculars from **B** and **A** in **F** and **G**.

ABFG is a rectangle equal in area to the given triangle.

By the method used in Fig. 16 find the required square **BKJH** which is equal to the rectangle **BFGA** and therefore equal to the given triangle.

To construct a rectangle equal in area to a given circle, Fig. 19.

Area of a circle is πR^2. If the short side of a rectangle is **R** the long side must be π**R** to make the area of this rectangle equal to that of the given circle.

Draw the circle, radius **R**($1\frac{1}{2}''$), and divide **R** into 7 equal parts.

Make AC equal to $3\frac{1}{7}$**R** and complete the rectangle **ACEO**.

Complete another rectangle having **AB** as one side and insert the length **X** of the other side in terms of **D**.

Complete the triangle, having **AC** as base, which will be equal in area to the given circle. What is the area of this triangle in terms of **D**?

Check the areas of the four figures (circle, two rectangles and triangle) in terms of **R** and **D** and also by numerical calculations.

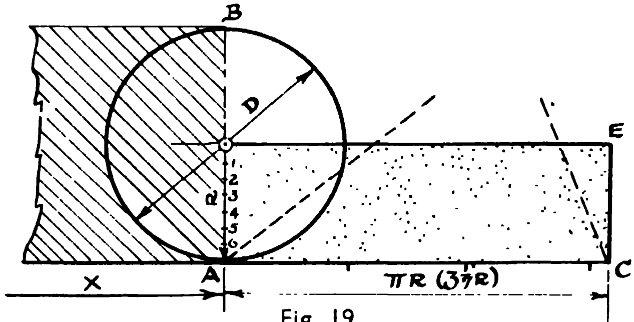


Fig. 19

To construct a triangle equal in area to a given polygon, Fig. 20.

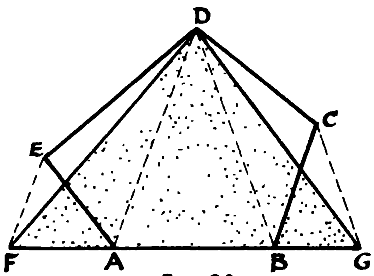


Fig. 20

Let **ABCDE** be the given polygon.

Join **DA** and through **E** draw **EF** parallel to **DA** meeting **BA** produced in **F**.

Join **DF**.

Similarly, join **DB** and through **C** draw **CG** parallel to **DB** meeting **AB** produced in **G**.

Join **DG**.

FGD is the required triangle which is equal in area to the given polygon **ABCDE**.

NOTE: *It is worthwhile to grasp this construction, since by this method even a complicated polygon can be reduced to a triangle.*

If similar figures are described on the sides of a right-angled triangle, the area of the figure on the hypotenuse is equal to the sum of the areas of the two other similar figures (Fig. 21).

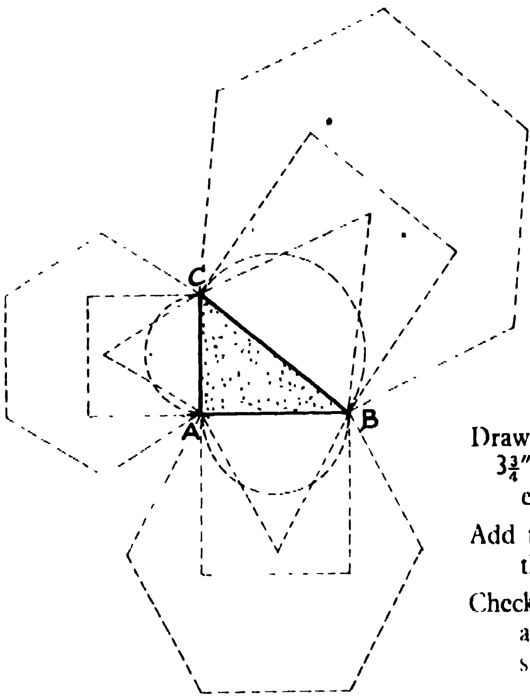


Fig. 21

Draw the right-angled triangle **ABC** (sides $3\frac{3}{4}''$, $3''$, $2\frac{1}{4}''$) and complete the squares on each side.

Add the other similar figures as shown by the broken lines.

Check your construction by calculating the areas in each of the four groups of similar figures.

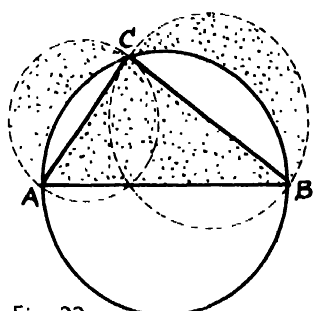


Fig. 22

Note : The construction (Fig. 22) is of practical value should it be required to find a ventilating duct, or pipe, where the area of section of one would replace the other two, e.g., a single water main of larger diameter to replace two smaller pipes.

Can you show that the triangle ABC is equivalent in area to the two crescent shaped figures?

DIVISION OF FIGURES INTO EQUAL AREAS

To divide a triangle into a given number of equal areas (say 3) by lines drawn from one of its angles, Fig. 23.

Let **ABC** be the given triangle.

Divide **AB** into the required number of equal parts (3).

Join **C1** and **C2** forming three triangles which are equal to each other.

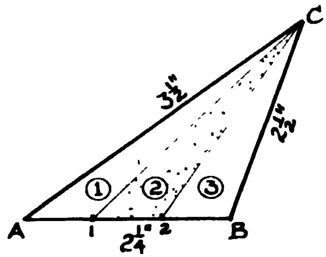


Fig. 23

To divide a triangle into a given number of equal areas (say 3) by lines drawn parallel to one of the sides, Fig. 24.

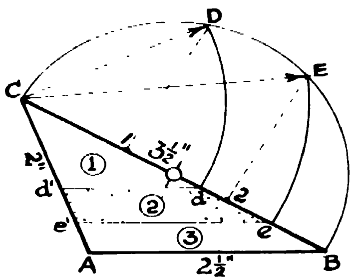


Fig. 24

Let **ABC** be the given triangle.

Divide **CB** (or **CA**) into the required number of equal parts (3).

Describe a semi-circle on **CB** and at **1** and **2** erect perpendiculars to **BC** meeting the semi-circle in **D** and **E**.

With centre **C** and radii **CD** and **CE** describe arcs meeting **CB** in **d** and **e**.

Through **d** and **e** draw **dd′** and **ee′** parallel to **BA** to divide the triangle into three equal areas.

To divide a parallelogram into a given even number of equal areas (say 4) by lines drawn from one of its angles, Fig. 25.

Divide two adjacent sides **AB** and **AD** into the required **even** number of equal parts (4).

Join **AC** (which divides the parallelogram into two equal areas) and **C2, C2′** (and other **even** numbers).

For a given odd number of equal areas (say 5), Fig. 26.

Join **C** to the **odd** numbers **C1, C1′**; **C3, C3′** (and other **odd** numbers).

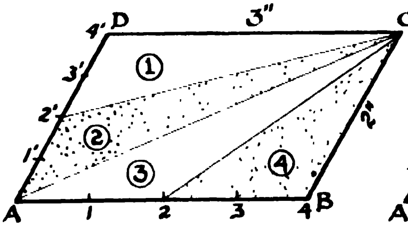


Fig. 25

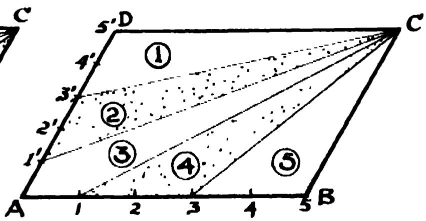


Fig. 26

To divide a circle into a given number of equal areas.

Fig. 27. By Sectors (say 5): Draw a circle, 3″ diam.

The angle at the centre is $\frac{360}{5} = 72°$.

Using dividers step off the distance **A-B** round the circumference **1, 2 - - 5** and join these points to the centre.

Fig. 28. By Concentric Circles (say 3): Draw a circle (3″ diam. **AB**).

Divide radius **OA** into three equal parts.

Describe a semi-circle on **OA** and erect perpendiculars at **1** and **2** meeting the semi-circle in **C** and **D**.

The required radii are **OC** and **OD**.

The "target" circles expose equal areas.

Fig. 29. By Semi-circles (say 4): Draw a circle (3″ diam. **AB**).

Divide **AB** into four equal parts and draw semi-circles through these points, above and below **AB**.

Note: *Circumferences of circles are proportional to their diameters so that the perimeters of the equal areas will also be equal.*

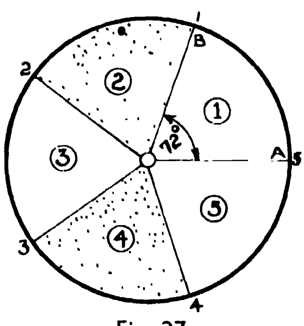


Fig. 27

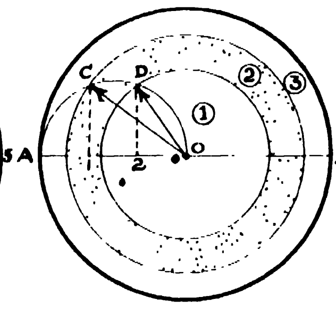


Fig. 28

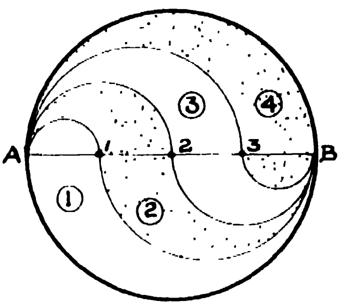


Fig. 29

LOCI

A Locus (or Path) is the line (or lines) traced by a point which moves, in one plane, under given definite conditions. The locus is found by plotting a series of points on the path and joining them with a line.

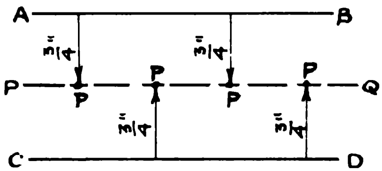


Fig. 30

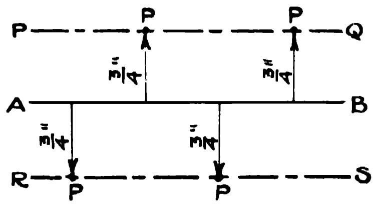


Fig. 31

(a) **PQ** (Fig. 30) is the locus of a point **P** which moves so that it is equidistant ($\frac{3}{4}''$) from the two parallel straight lines **AB** and **CD**.

(b) In Fig 31 there are two branches (loci) of a point **P** which moves so that it is equidistant from the straight line **AB**, viz. **PQ** and **RS**

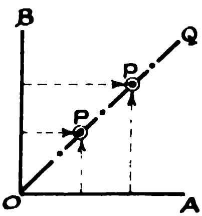


Fig. 32

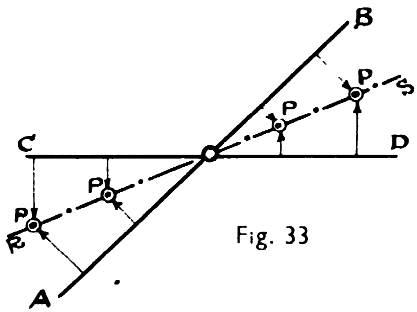


Fig. 33

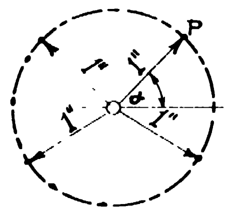


Fig. 34

(c) **OQ** (Fig. 32) is the locus of a point **P** which moves so that it is equidistant between two straight lines **OA** and **OB** meeting at **O**.

(d) **RS** (Fig. 33) is the locus of a point **P** which moves so that it is equidistant from two straight lines intersecting at **O**.

(e) The circumference (Fig. 34) is the locus of a point **P** which moves so that it is 1″ (radius) from the centre of the circle. Its position is determined by one linear measurement (1″) and the vectorial angle α.

An analogy for this would be the path traced out by a weight being swung rapidly at the end of a cord or the orbit of a satellite (moon or "sputnik") travelling round the earth and constrained by natural gravitational forces (earth and moon) and gravitational and initial forces given at launching.

Note : When the locus is determined by **one** condition, the point can have any position on the path. When **two** conditions are to be fulfilled, the point is confined to a limited number of definite positions. These positions are obtained by the method of " Intersection of Loci."

Parallels of latitude are examples of loci of all places on a given latitude.

Meridian lines are examples of loci of all places on a given longitude.

A place is fixed at the point of intersection of these two loci, i.e., latitude and longitude.

LOCI OF MECHANISMS

The loci of mechanism are the diagrammatic representations of interdependent moving parts in a machine.

A Mechanism (or movement) consists of a combination of parts for transmitting or converting motion. Each part has one degree of freedom to move and no part in the mechanism can move without other parts changing their positions in a definite way. *Constraint* is an important part of mechanism and is the function of keeping the parts within the prescribed limits of the movement.

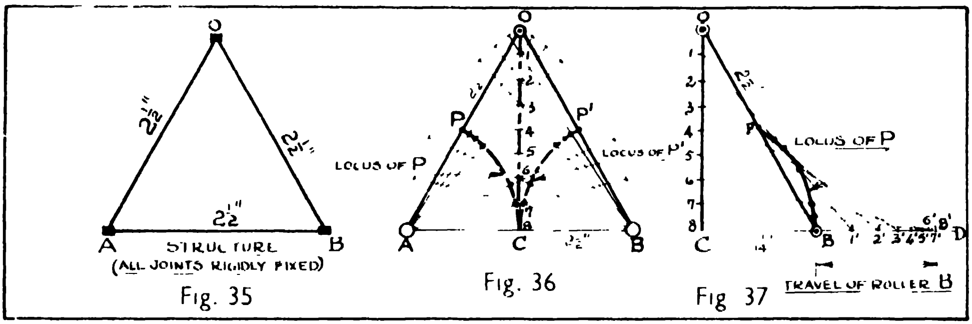


Fig. 35 Fig. 36 Fig 37

Fig. 35 shows three rods and if they are permanently **fixed** at **A**, **B** and **O** they are constrained to form a rigid structure

In Fig. 36, A and **B** are fixed points, about which the links **AO** and **BO** are free to turn. Suppose these rods are detached at **O** so that they can slide past one another until they reach a horizontal position, it will be seen that the locus of **O** will be the vertical line **O-C** and the loci of **P** and **P** (mid-points on the rods) can be plotted for each of the positions 0, 1 - - 8 to trace out the curves **P-C** and **P′-C**

In Fig. 37, C and **O** are fixed points and at the end of the link **OB** there is a roller which is constrained to slide along the horizontal line **B-D** as **O** moves through the eight positions (0, 1 - - 7, 8) on **OC**. The corresponding positions of the roller will be B, 1′ - - 7, 8 . The locus of **P** (mid-point on **OB**) can be plotted to trace out the curve **PB.**

Fig. 38 shows a mechanism where the crank **OA** (3″) is turned about centre **O** by the rod **BA** (3″) as the point **B** moves in a horizontal path through **B** and **D.**

Mark the positions of **B** and plot the locus of a point **P**, at the centre of the rod, for one revolution of the crank.

Divide one quarter of the crank circle into equal parts (say 6). As **A** reaches each of these positions (see 2) mark the corresponding positions of **B(2′)** on **OC** and of **P** on **AB.** Draw a smooth curve through **P°P¹′ - - - P⁶** for the locus of **P** during one quarter of a revolution of the crank. The complete locus may be obtained, by similar methods, for the remaining three quarters of the revolution. Alternatively, the curve can be completed by using tracing paper.

Note : Much time can be saved in the plotting of loci by using a strip of cardboard as a gauge.
Mark off the length of the rod and the positions **A, B** and **P**.
Place **A** at its position on the crank circle, say 8, fix **B** on **CO** and the point **P⁸** can be located all as shown for this position on the diagram.

Fig. 39 shows the " slider crank " mechanism as used in a steam engine. The reciprocating movement of the slider is converted into rotary motion by the movement of the crank. If a pulley were fixed on **O** (crankshaft) the important method of power transmission by belt drive can be obtained.

EXERCISE 1 — Use 22″ × 15″ paper — PLATE 1

Figs. 35, 36, 37 (page 23). Draw these figures to the sizes given and plot the loci PC, P′C and PB as shown.

Fig. 38. Draw this figure.

Mark the positions of **B** on **CD** and plot the locus of the mid-point **P** on the rod for one revolution of the crank.

Fig. 39. Draw this figure.

Mark the positions of the slider and plot the locus of the mid-point **P** on the rod for one revolution of the crank.

PLATE 1

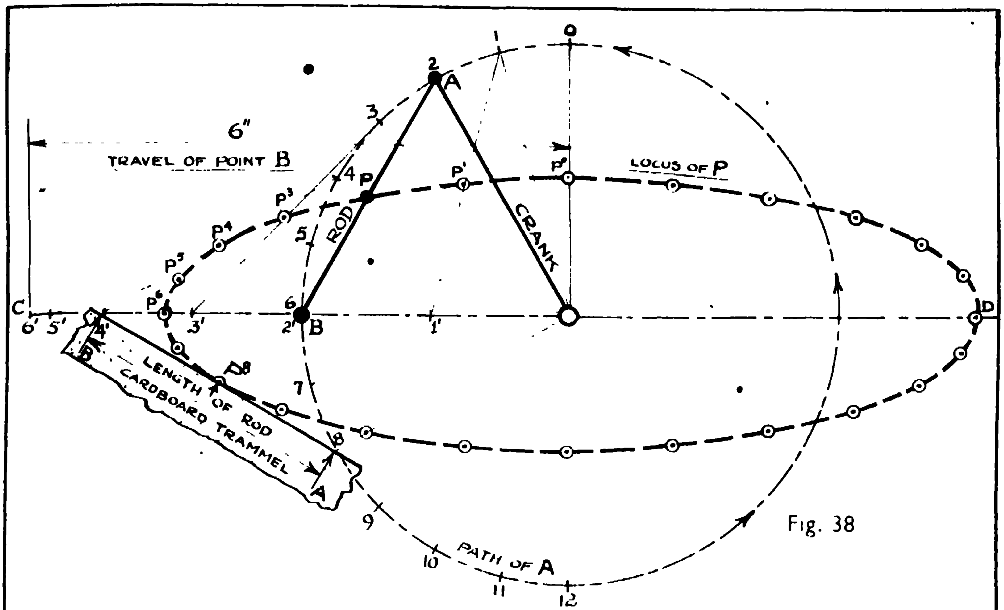


Fig. 38

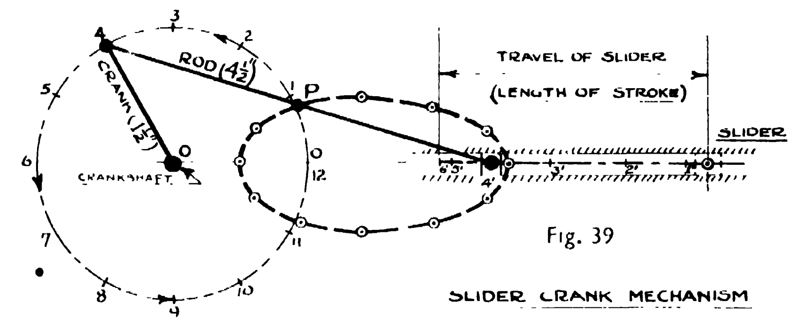


Fig. 39

SLIDER CRANK MECHANISM

EXERCISE 2 — Use 22″ × 15″ paper — PLATE 2

Lever Crank Mechanism, Fig. 40. The crank **OA** has the lever **O′B** as a follower and **AB** as a connecting link. Trace the path of **B** and plot the locus of a point **P** on **AB** for one revolution of the crank.

Draw the mechanism, to the given sizes, in the position shown

Divide the crank circle into 12 equal parts and proceed as shown for the first three positions, marking the corresponding positions of **B** and **P.**

What angle is swept out by **O′B**? State the distance of the travel of **B.**

Double Lever Mechanism, Fig. 41. The rods **OA** and **O′B** oscillate about **O** and **O′** Trace the path of **B** and plot the locus of a point **P** on **AB** while **OA** turns through 120°.

Watt's Straight Line (or Parallel) Motion, Fig. 42. This mechanism is arranged so that the locus of the mid-point **P** on the connecting link **AB** is a straight line throughout the greater part of its movement.

Mark off on the arc **CD** a series of small arcs on each side of **A** and fix the corresponding positions of **B** on arc **EF** and of the mid-point **P** as shown in the figure

Plot the locus of **P** during its straight line portion and continue throughout the entire movement of the mechanism What is the shape of the locus?

Fig. 43. Find the locus of a point **P**, moving in the same plane, so that its distance from a fixed point F is equal to the perpendicular distance of the point **P** from a straight line **AB**. Plot the point to a limit of 3″

Fig. 44. **A** and **B** are two fixed points, 3″ apart, in a horizontal line

Plot the locus of a point **P** so that the sum of its distances from **A** and **B** is equal to 4″.

Do you recognise the shape of the curve?

Fig. 45. **AD** and **BC** are two cranks connected by a coupling rod **DC**, representing the mechanism on the driving wheels of a locomotive.

Plot the locus of the mid-point **P** on the "coupler."

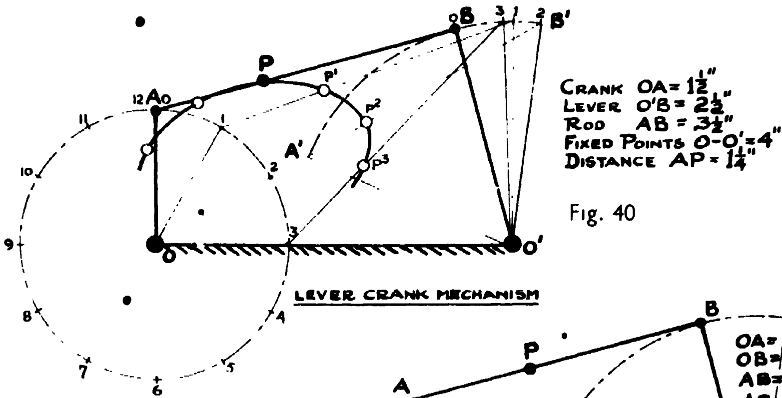


Fig. 40

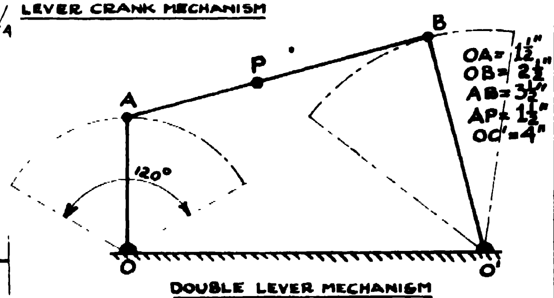


Fig. 41

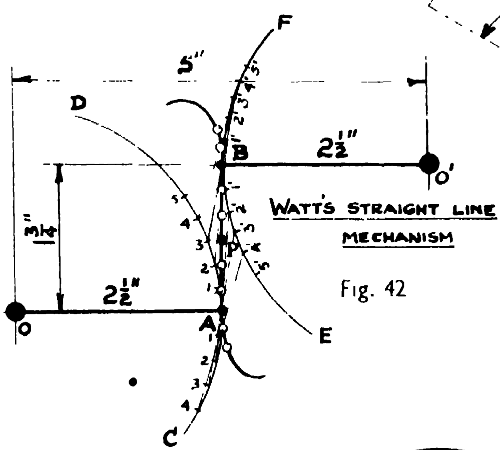


Fig. 42

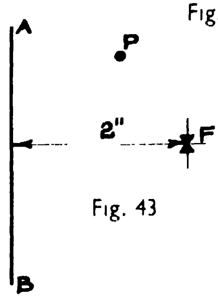


Fig. 43

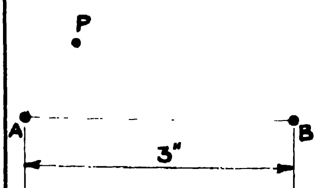


Fig. 44

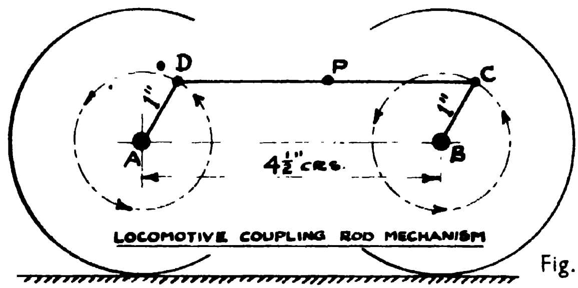


Fig. 45

CHAPTER 2

DEVELOPMENT OF SURFACES — PRISMS — PYRAMIDS — AUXILIARY VIEWS (ELEVATIONS AND PLANS) — MISCELLANEOUS EXERCISES

THE DEVELOPMENT OF SURFACES

The " *development* " of the surface of a solid plays an important part in many trades, *e.g.*, sheetmetal work, plumbing, boxmaking, etc. Much of the work undertaken in these trades is to cover, with thin material, the surface of a given solid, or to enclose a definite volume. The converse of this operation would be to unwrap the surface of the given solid, or open out its surface, into one plane, *viz.*, the plane of the thin material. In your case "*the plane of the thin material*" will be that of the *drawing paper*. Thus the **development** of the surface of a solid is the **folding out** of the various surfaces into **one plane.** It is interesting to unfold some of the various cardboard wrappers or metal containers in which goods are supplied and to study how they have been developed and folded.

PRISMS

The Surface Development of a Cube : Fig. 46.

As a cube is bounded by six equal square faces, the development must be six equal squares. From a practical point of view, these squares would not be made separately, as this would entail the joining together of these six separate squares to form the cube.

A better method is to make as much use as possible of a " folded " edge (shown by broken lines on the drawing).

The Surface Development of a Square Prism : Fig. 47.

As the cube is a particular case of the square prism, the method of obtaining this development will be obvious from the figure and previous exercise.

The Surface Development of a Triangular Prism : Fig. 48.

Construct the triangles having sides **a**, **b**, **c**, (1", $1\frac{1}{2}$", 2") forming the top and base of the prism.

Draw the rectangles forming the faces all as shown in the figure.

The Surface Development of a Regular Hexagonal Prism : Fig. 49.

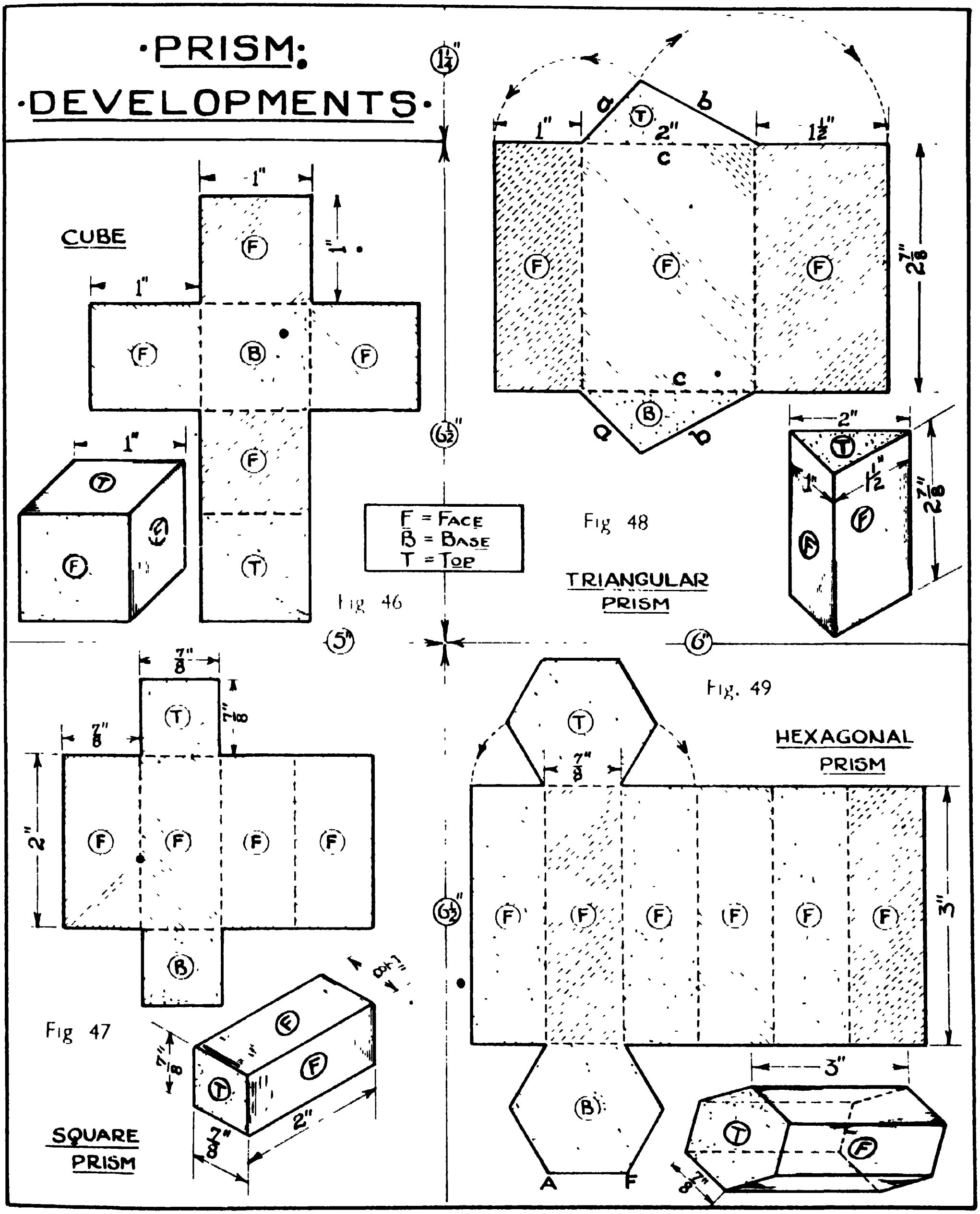
Let **AF** be the length of one edge of the base.

Construct the regular hexagon forming the base.

On the side opposite to **AF** draw a rectangle having length equal to the height of the prism.

Draw six similar rectangles as shown.

Complete the hexagon forming the top of the prism.


·PRISM:
·DEVELOPMENTS·
CUBE
Fig 46
F = FACE
B = BASE
T = TOP
Fig 48
TRIANGULAR
PRISM
Fig 47
SQUARE
PRISM
Fig. 49
HEXAGONAL
PRISM

The Surface Development of a Square Pyramid : Figs. 50, 51, 52.

There are three different methods for the development of this solid. All are correct ; but from a practical point of view the method of Fig. 52 is preferable. The methods of Figs. 50, 51 would entail much waste of time and material.

Fig. 52.

On **AB** construct the square base, and one face of the pyramid (**AOB**).
With centre **O** and radius **OB** describe the arc **BCDE**.
Obtain the points **C, D, E,** by " stepping " round this arc with a radius equal to **AB**.
Join **OB, OC, OD,** with broken lines, indicating where a fold will be required on the surface, and **OE** with a " full " line.
Join **BC, CD** and **DE** to complete the development.

N.B.—*Fig. 53 shows how the various lengths on a right square pyramid are obtained from given data.*

EXERCISE 3 — Use 22″ × 15″ paper — **PLATES 3 and 4**

Place the paper on the board with its long edge horizontal, and divide it vertically into two equal parts to accommodate the following problems :

PLATE 3

Fig. 46. Draw the surface development of a 1″ cube.

Fig. 47. Draw the surface development of a $\frac{7}{8}$″ square prism 2″ long.

Fig. 48. Draw the surface development of a triangular prism, $2\frac{7}{8}$″ long, having edges of base 1″, $1\frac{1}{2}$″, 2″.

Fig. 49. Draw the surface development of a $\frac{7}{8}$″ hexagonal prism 3″ long.

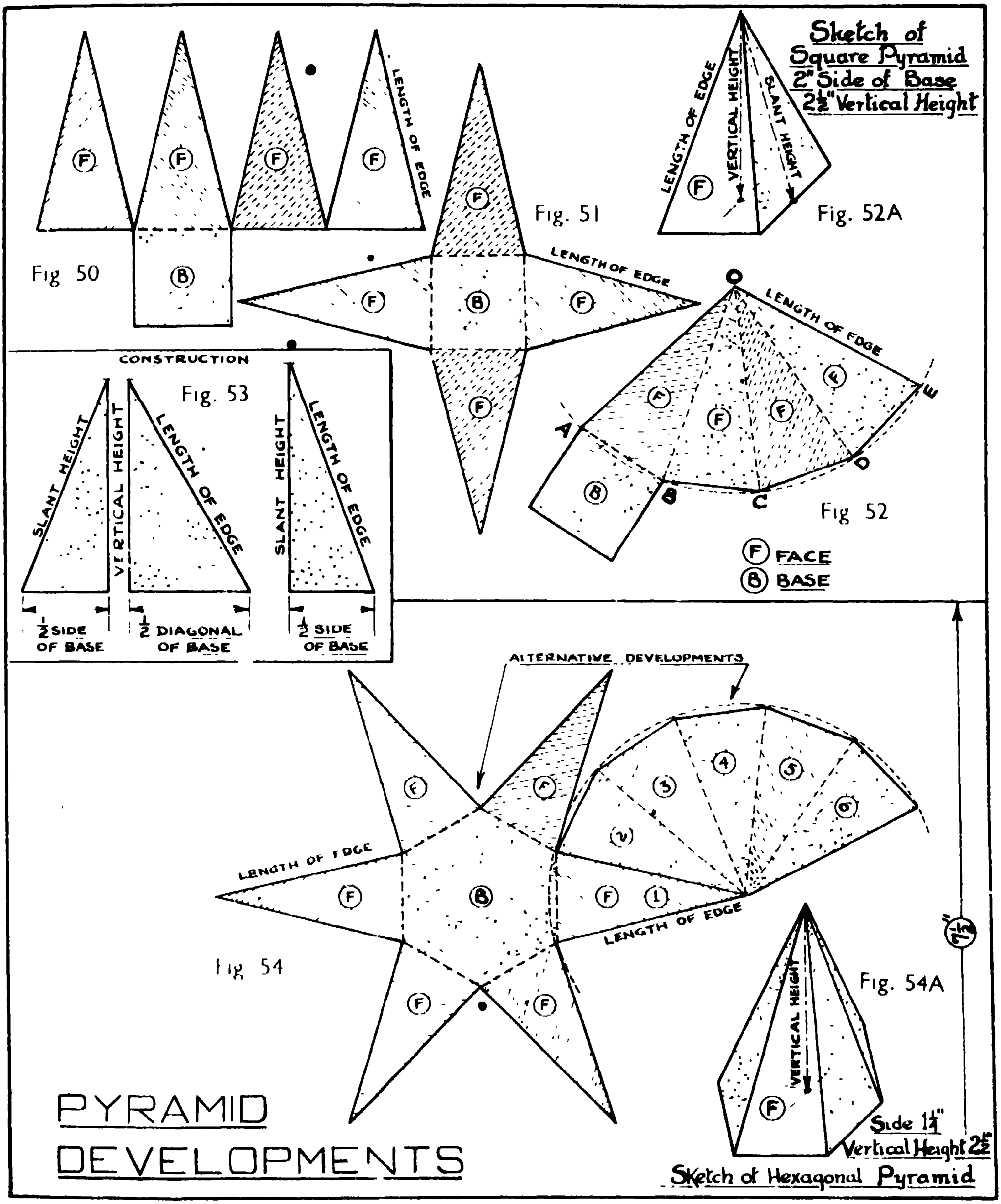
PLATE 4

Fig. 52A. Draw the surface development of a 2″ square pyramid $2\frac{1}{2}$″ vertical height.

Fig. 54A. Draw the surface development of a $1\frac{1}{4}$″ hexagonal pyramid, $2\frac{1}{2}$″ vertical height, by the two methods shown.

MODEL MAKING

Select two or three of the above developments and cut round the outline, leaving one side, or edge of base, attached to the paper. Fold up the " cut-outs " to represent the solids.


Sketch of Square Pyramid 2" Side of Base 2½" Vertical Height
LENGTH OF EDGE
VERTICAL HEIGHT
SLANT HEIGHT
Fig 50
Fig. 51
Fig. 52A
Fig 52
Fig. 53
CONSTRUCTION
SLANT HEIGHT
LENGTH OF EDGE
½ SIDE OF BASE
½ DIAGONAL OF BASE
F FACE
B BASE
ALTERNATIVE DEVELOPMENTS
Fig 54
Fig. 54A
7½"
Side 1¼"
Vertical Height 2½"
Sketch of Hexagonal Pyramid
PYRAMID DEVELOPMENTS

EXERCISE 4 — Use one half of 22″ × 15″ paper — **PLATE 5**

Fig. 55 shows the sketch of a cube with certain portions removed.

Draw, to a scale of full size, in the positions shown :—

(a) The given elevation.

(b) The plan.

(c) The true shape of the sloping surface.

(d) The development of the complete surface.

Fig 56 shows the sketch of an equilateral triangular prism with a portion removed.

Draw, to a scale of full size, in the positions shown :—

(a) The plan and an elevation looking in the direction of the arrow.

(b) The development of the complete surface.

Note : *It will be necessary for the development to find the true lengths of the edges forming the sliced surface since these are inclined to both planes.*

PLATE 5

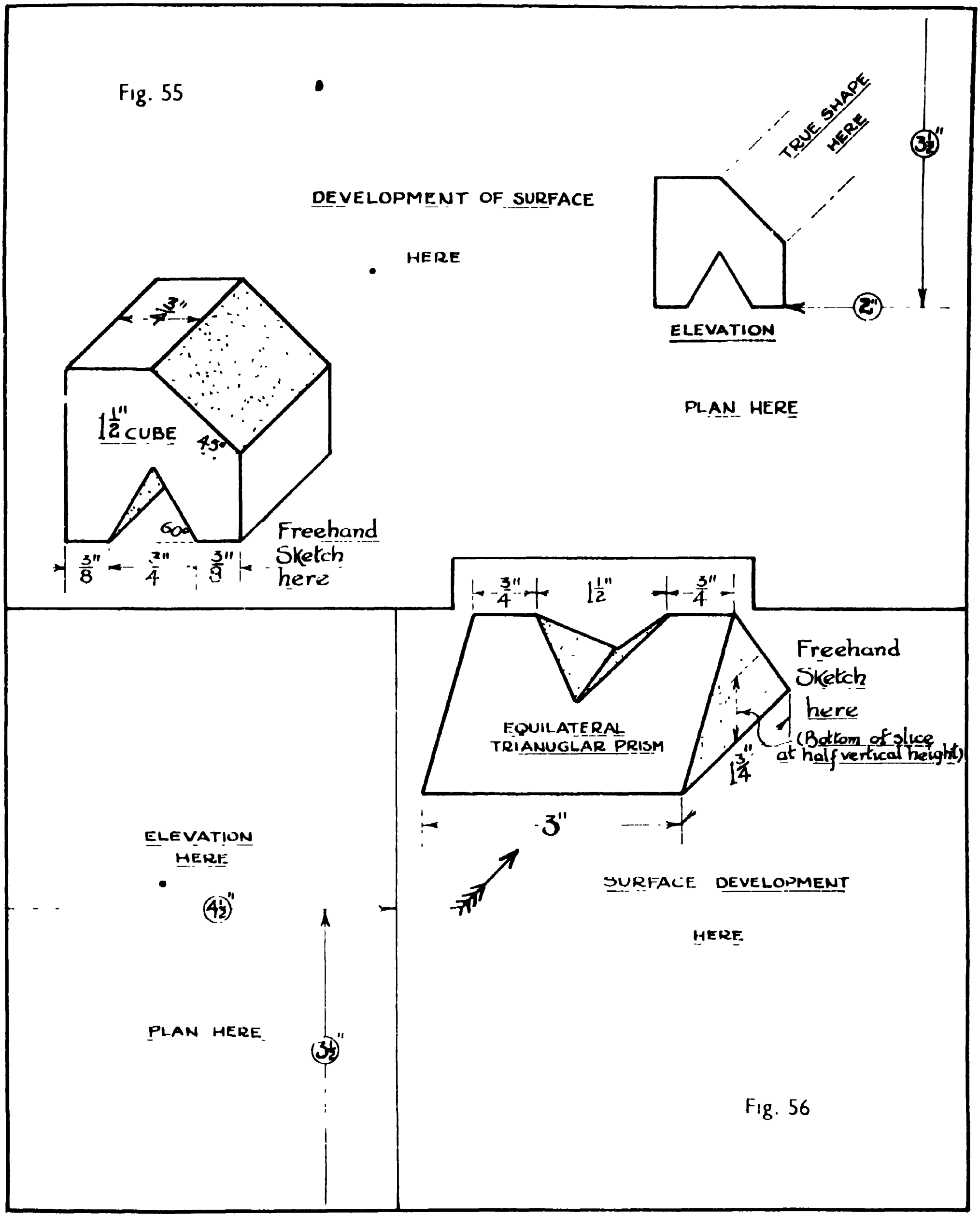


Fig. 55
DEVELOPMENT OF SURFACE
HERE
TRUE SHAPE
HERE
3½"
ELEVATION
2"
PLAN HERE
1½" CUBE
¾"
45°
60°
3/8"
3/4"
3/8"
Freehand
Sketch
here
3/4"
1½"
3/4"
EQUILATERAL
TRIANUGLAR PRISM
Freehand
Sketch
here
(Bottom of slice
at half vertical height)
1¾"
3"
SURFACE DEVELOPMENT
HERE
ELEVATION
HERE
4½"
PLAN HERE
3½"
Fig. 56

EXERCISE 5 — Use one half of 22″ × 15″ paper — **PLATE 6**

Fig. 57 shows the plan and elevation of a triangular prism with a portion removed.

Draw, to a scale of full size, in the positions shown :—

(a) The given views.
(b) The true shape of the cut surface.
(c) The development of the complete surface.

Fig. 58 shows the elevation of an equilateral triangular prism with a portion removed.

Draw, to a scale of full size, in the positions shown :—

(a) The given elevation.
(b) The plan.
(c) The development of the complete surface.

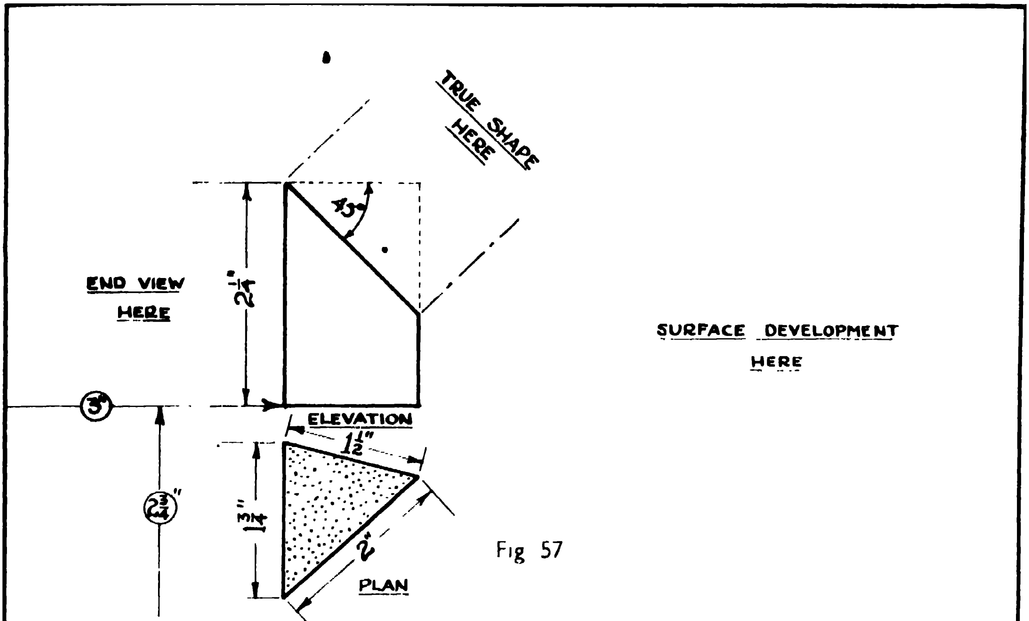

TRUE SHAPE HERE
END VIEW HERE
45°
$2\frac{1}{4}$"
SURFACE DEVELOPMENT HERE
3"
ELEVATION
$1\frac{1}{2}$"
$2\frac{3}{4}$"
$1\frac{3}{4}$"
2"
PLAN

Fig 57

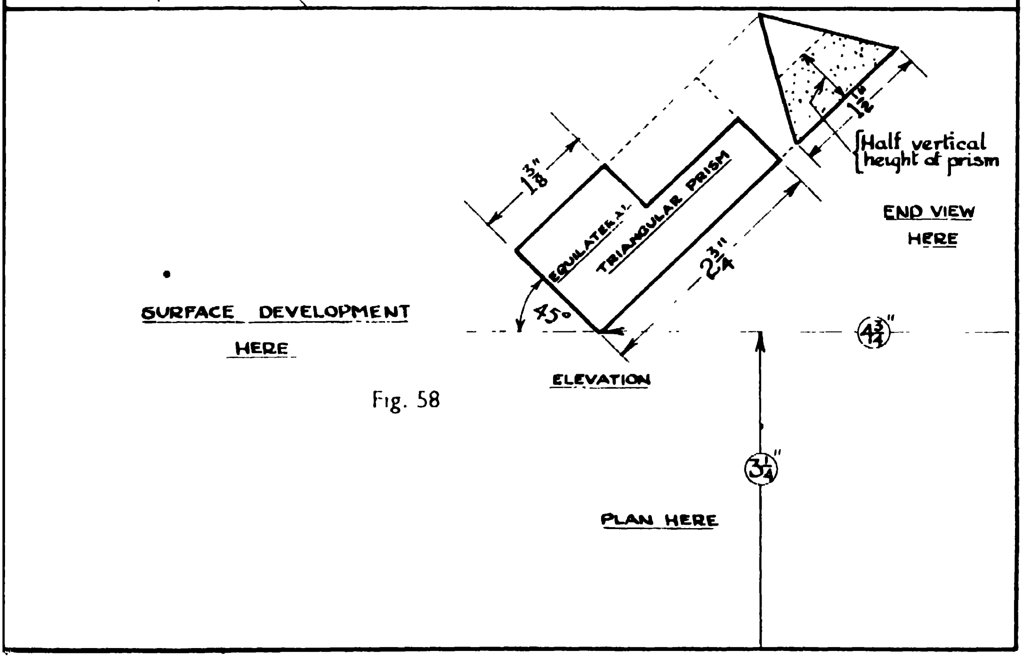

$1\frac{1}{2}$"
Half vertical height of prism
$1\frac{3}{8}$"
EQUILATERAL TRIANGULAR PRISM
END VIEW HERE
$2\frac{3}{4}$"
45°
SURFACE DEVELOPMENT HERE
$4\frac{3}{4}$"
ELEVATION
$3\frac{1}{4}$"
PLAN HERE

Fig. 58

EXERCISE 6 · Use 22″ · 15″ paper — **PLATE 7**

Fig. 59 shows the dimensioned sketch of a shallow tray with sloping sides.

Draw, to a scale of full size, in the positions indicated:

(a) The given plan.

(b) The elevation projected from the plan.

(c) The development of the surface.

Copy the given sketch.

Fig. 60 shows the dimensioned sketch of a lamp shade, formed on a wire frame, in the shape of the frustum of a hexagonal pyramid.

Draw, to a scale of quarter full size, in the positions indicated.—

(a) The given elevation.

(b) The end view projected from the elevation.

(c) The development of the surface.

Copy the given sketch.

What is the actual length of wire required to make the frame?

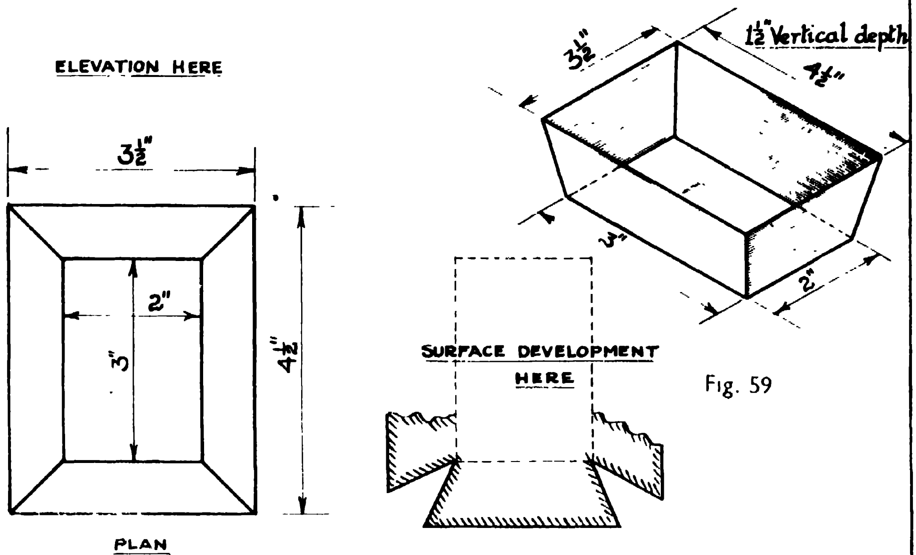

ELEVATION HERE
3½"
2"
3"
4½"
PLAN
1½" Vertical depth
3½"
4½"
3"
2"
SURFACE DEVELOPMENT HERE

Fig. 59

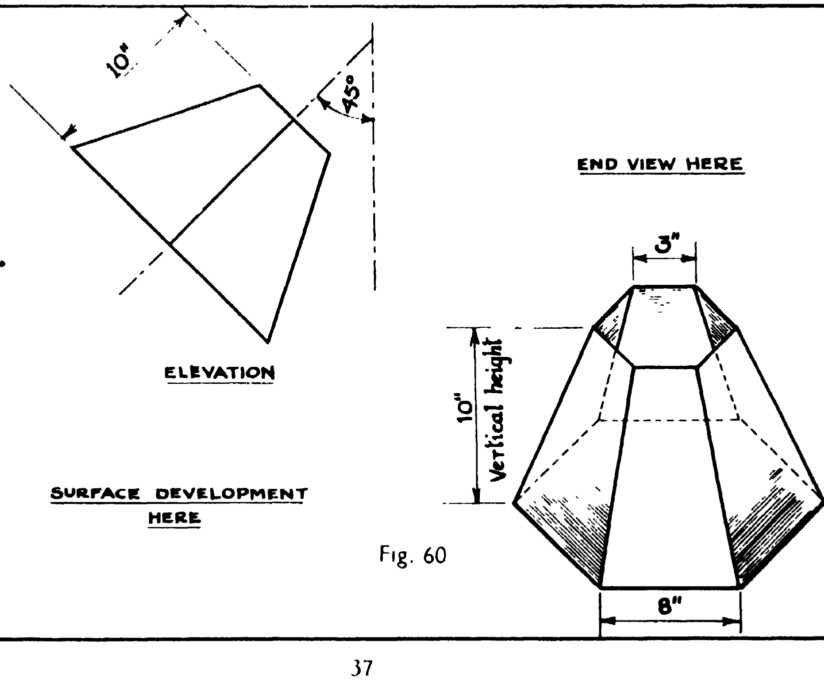

10"
45°
ELEVATION
END VIEW HERE
3"
10"
Vertical height
8"
SURFACE DEVELOPMENT HERE

Fig. 60

EXERCISE 7 — Use 22″ × 15″ paper — PLATE 8

Fig. 61 shows the sketch of a silver cream jug in the shape of a truncated regular hexagonal pyramid, with the spout in the shape of an inverted triangular pyramid.

Draw, to a scale of full size, in the positions shown :—

(a) The complete plan.

(b) The elevation.

(c) The development of the surface including the base, handle and spout.

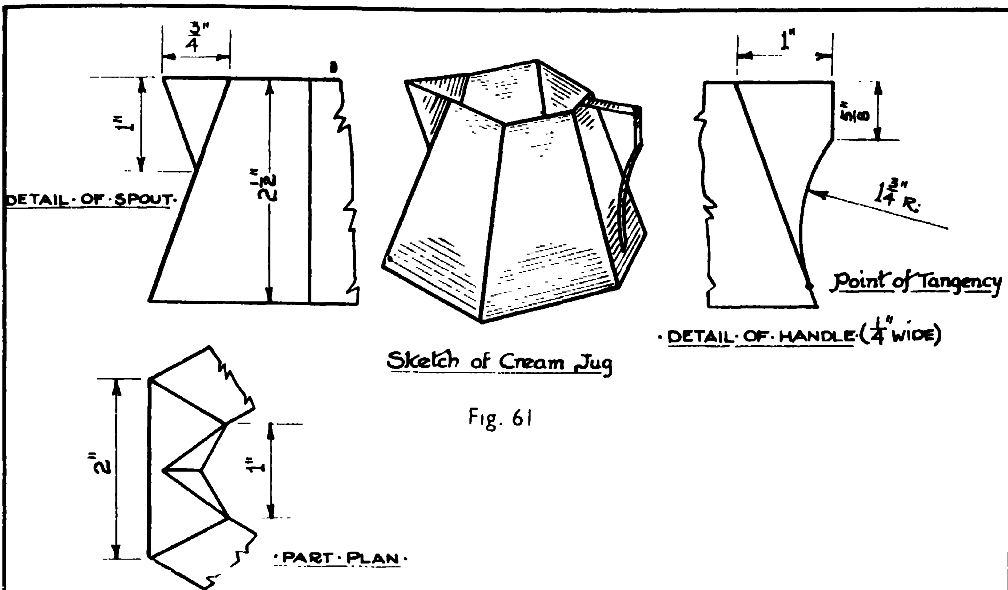


Fig. 61

· ELEVATION · HERE ·

· DEVELOPMENT · OF · SPOUT ·
· HERE ·

· PLAN · HERE ·

14"

· DEVELOPMENT · OF · HANDLE · HERE ·

· DEVELOPMENT · OF · JUG · INCLUDING · BASE · HERE ·

EXERCISE 8 — Use 22″ × 15″ paper — PLATE 9

The elevation and incomplete plan of a clock turret, in the shape of the frustum of a square pyramid (astride a pitched roof), is shown. It is surmounted by a cube (containing the clock face) and a square pyramid.

Draw, to a scale of 1″ to one foot, in the positions shown :—

(a) The given elevation.

(b) The complete plan.

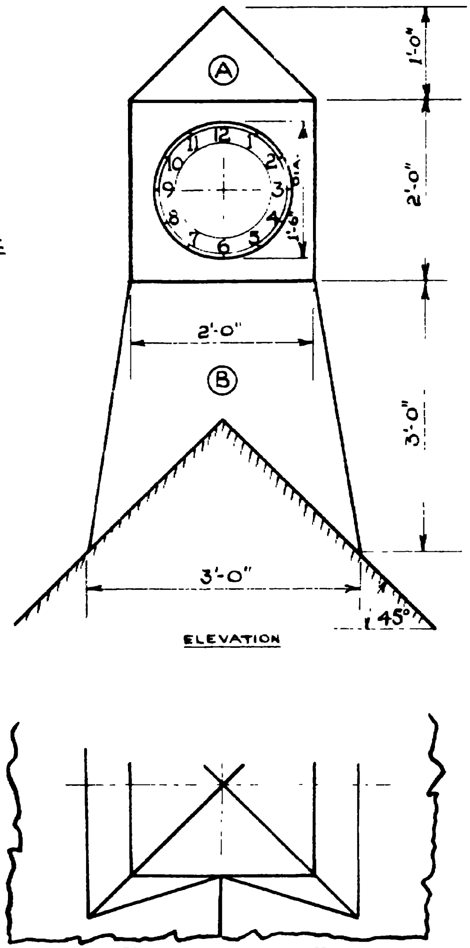
(c) The surface development of **A** in one piece.

(d) The surface development of **B** by the method of true lengths of lines.

(e) The true shape of the hole in the roof.

PLATE 9

DEVELOPMENT OF A HERE



DEVELOPMENT OF B HERE

TRUE SHAPE OF HOLE
IN THE ROOF HERE

AUXILIARY VIEWS — PLATE 10

Sometimes the conventional views of plan, elevation and end view do not provide sufficient information about an object. It is then necessary to introduce an **AUXILIARY PLANE** upon which a desired view can be projected. This procedure is convenient not only when a complete view is desired, but also when a true shape of surface, or of section, is required.

For example, Fig. 62 shows the sectional plan of a door in the corner of a building. Neither the elevation nor the end view, projected from this plan by conventional methods, shows the *actual* width of the door opening, because the surface of the door is in a plane which is at 45° (**X′-X′**) to the conventional Vertical Plane (**X-X**). The *actual*, or *true*, elevation would be obtained by direct projection on to an inclined plane (called **Auxiliary Vertical Plane**) and the view so obtained is referred to as an **Auxiliary Elevation** (Fig. 63). It should be noted that respective heights **above the HP** (or **X-X** line) remain the same in the three views (Elevation, End View and Auxiliary Elevation) but only the *Auxiliary Elevation* gives the *true* width of the door and its opening.

Any plane, other than the conventional planes, is referred to as an **AUXILIARY INCLINED PLANE** and projection methods, similar to those for an Auxiliary Elevation, can be used to obtain an **AUXILIARY PLAN**. In this case, respective distances **from the Vertical Plane** remain the same and will be set off below the **X′-X′** line (see page 43).

PLATE 10

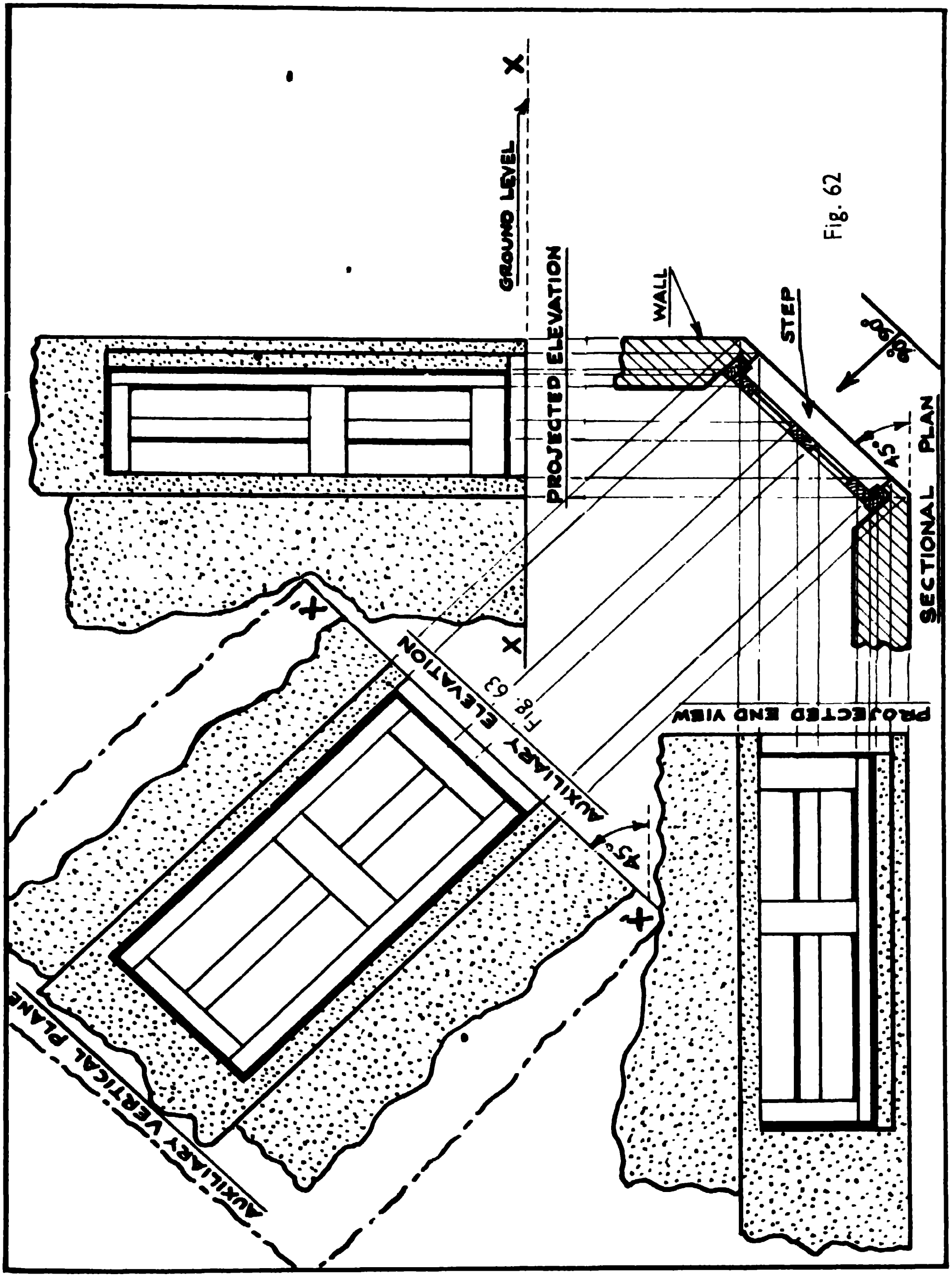


Fig. 62

Fig. 63

AUXILIARY ELEVATION

An Auxiliary Elevation is obtained by projection on an **Auxiliary Vertical Plane** (**AVP**) which is not parallel to **VP** (Fig. 64).

- **P^1** is the projection of a point **P** on **VP**.
- **P^2** is its projection on **EP**.
- **P^3** is its position on **AVP** inclined at angle α to **VP**.
- **P^4** is its projection on **HP**.

It will be noticed that the height of **P** (i.e., **P^4-P**) above the **HP** remains the same, as shown by the arrowed lines, at the positions **P^1,P^2,P^3**.

Fig. 65 shows the plan of the **AVP** inclined at an angle α to **VP**. The conventional elevation and plan of the point are shown at **P^1** and **P^4** on the **VP** and **HP** respectively. The **AVP** is projected at right angles on a base line **X^1 - X^1** inclined at an angle α to **X - X** line. The position **P^3** on this plane is obtained by projection from the plan and at the same height above **X^1 - X^1** as **P^1** is above **X - X** in **VP**.

Note : *To obtain the position of any point in an Auxiliary Elevation, project the point from its position in the plan at right angles to AVP and make its distance above X^1 - X^1 equal to the corresponding height above X - X in the elevation*

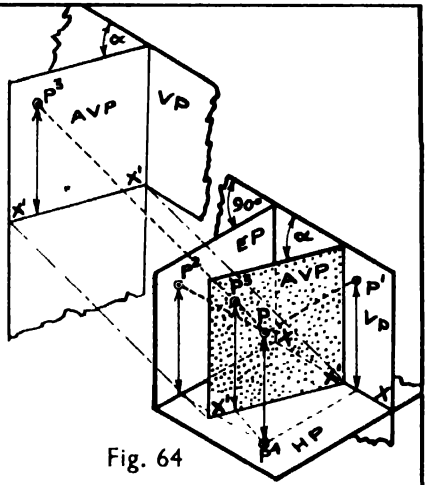


Fig. 64

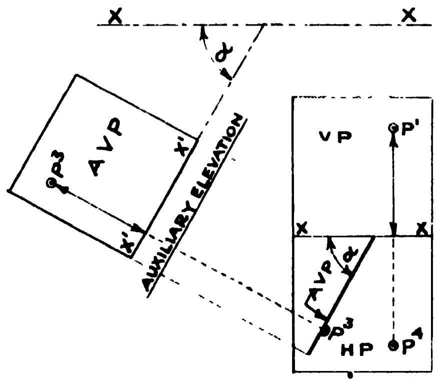
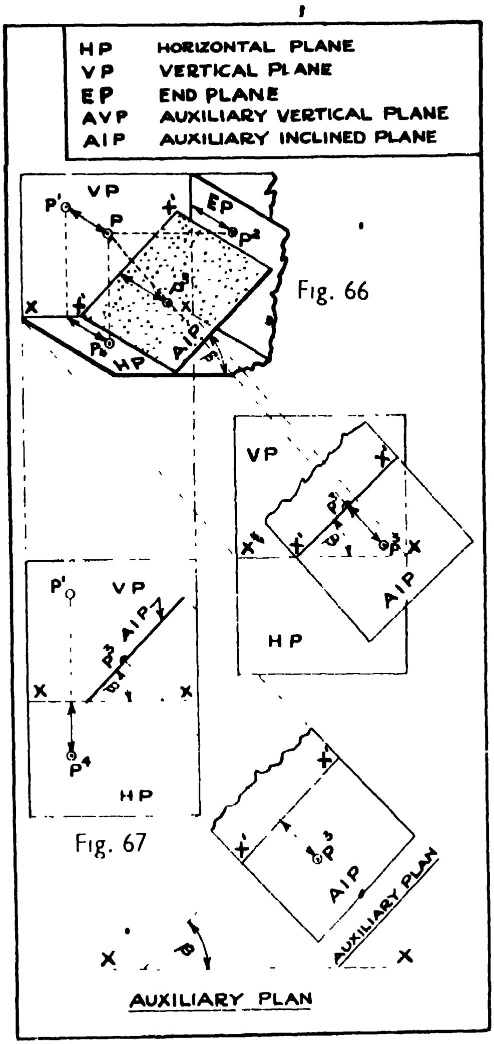


Fig. 65

AUXILIARY ELEVATION



AUXILIARY PLAN

An Auxiliary Plan is obtained by projection on an **Auxiliary Inclined Plane (AIP)** which is not parallel to **HP** (Fig. 66).

P¹ is the projection of a point **P** on **VP**.
P² is its projection on **EP**.
P³ is its position on **AIP** inclined at angle β to **HP**.
P⁴ is its projection on **HP**.

It will be noticed that the distance of **P** from **VP** (i.e., **P¹ - P**) remains the same, as shown by the arrowed lines, at the positions **P²**, **P³**, **P⁴**.

Fig. 67 shows the elevation of the **AIP** inclined at an angle β to **HP**. The conventional elevation and plan of the point are shown at **P¹** and **P⁴** on **VP** and **HP** respectively. The **AIP** is projected at right angles on a base line **X¹ - X¹** inclined at angle β to **X - X** line. The position **P** on this plane is obtained by projection from the elevation and at the same distance from **X¹ - X¹** as **P⁴** is below **X - X** in **HP**.

Note : *To obtain the position of any point in an Auxiliary Plan, project the point from its position in the elevation at right angles to AIP and make its distance below X¹ -X¹ equal to the corresponding distance below X -X in the plan.*

It is interesting to reason out that when the angle β becomes 90° to **HP** the **Auxiliary Plan** is the conventional End View as shown at **P²** (Fig. 66).

EXERCISE 9 — Use 22″ × 15″ paper — PLATE 11

Plate 11 shows the plan and elevation of a $1\frac{3}{4}''$ square prism, $2\frac{1}{4}''$ high, in a position $\frac{1}{2}''$ above **HP** and having one face inclined at 30° to **VP**.

Draw, to a scale of full size, in the positions shown :—

(a) The given plan and elevation. Note that each pair of top and base points on the four vertical edges of the cube in the plan (e.g., **A.** **E**; **B.** **F**; **C.** **G**; **D.** **H**) are the same distance from **VP**.

(b) The full end view looking from the left.

(c) The sectional end view on **S-N** looking from the right.

(d) The auxiliary elevation on a plane inclined at 30° to **VP** which will give the true shape of one face of the prism. Project points from the plan, at right angles to $\mathbf{X^1\text{-}X^1}$, and take heights from the elevation.

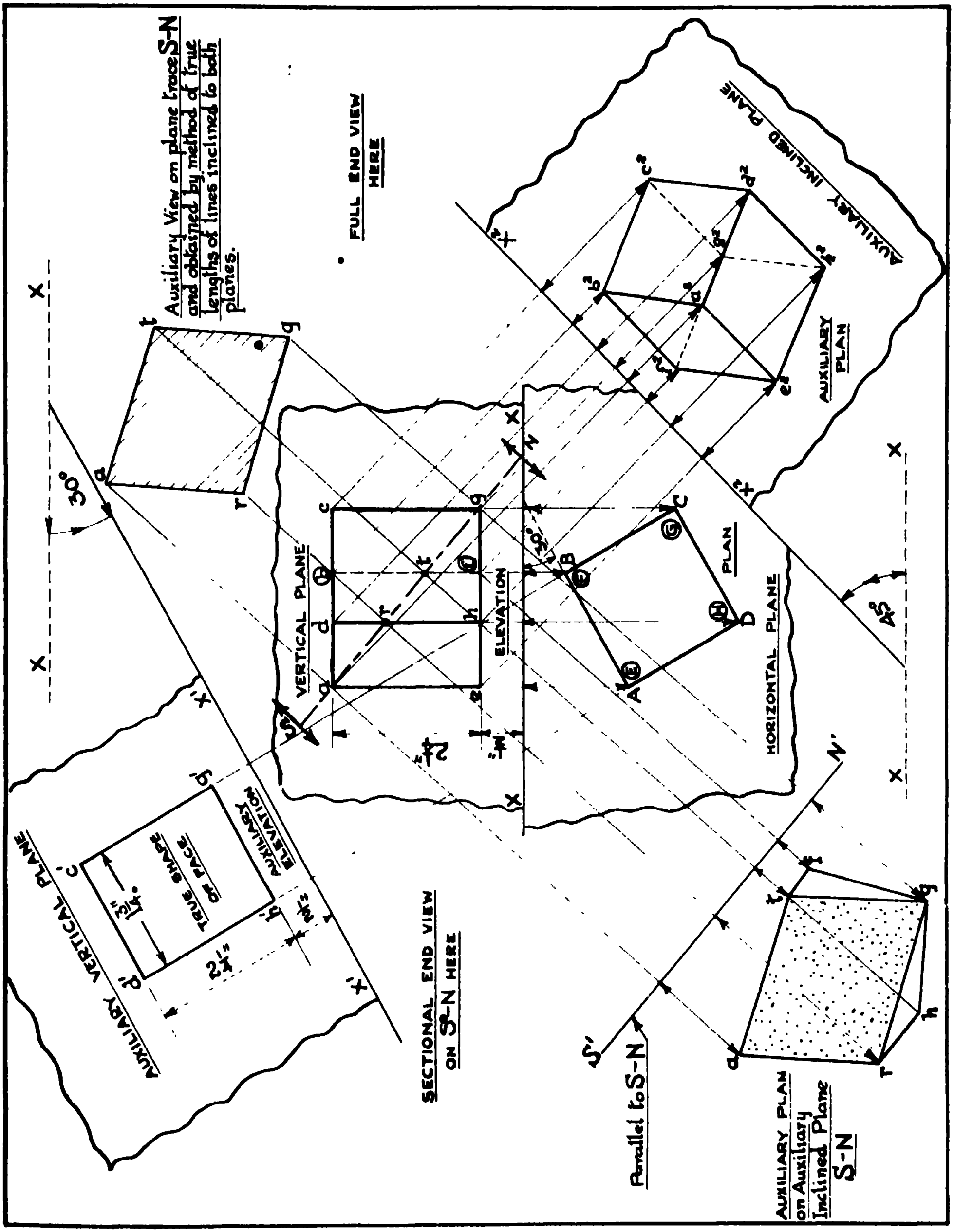
(e) The auxiliary plan on **AIP** plane inclined at 45° to **HP**. Project points from the elevation and make the lengths of the arrowed lines $\mathbf{X^2\text{-}X^2}$ equal to the lengths of the corresponding arrowed lines below **X-X** in the plan.

(f) The auxiliary plan taken on the line of section **S-N** by the same methods as (e).

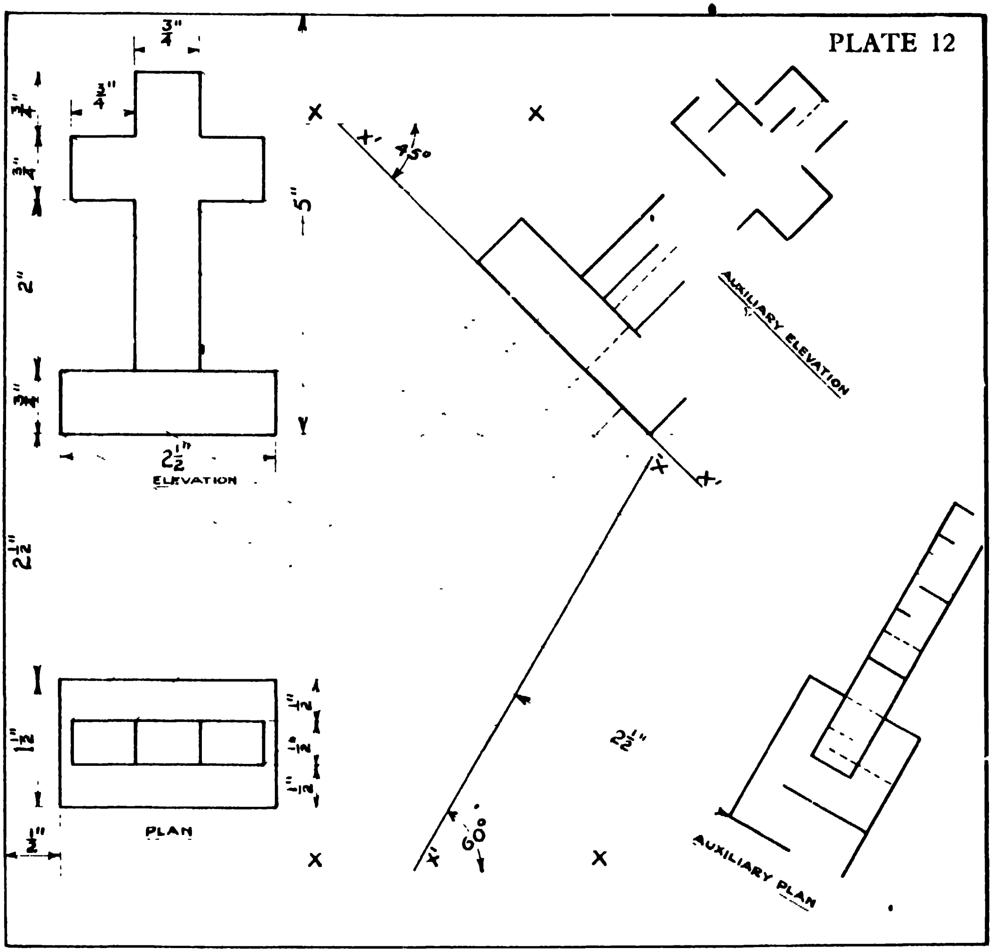
(g) The true shape, of the section **S-N** by the method of true lengths of lines inclined to both planes.

Note : *The dotted surface* (**atgr**) *in* (f) *will be the same as the hatched section in* (g) *because each shows the actual " cut " surface of the prism.*

PLATE 11



Auxiliary View on plane trace S-N and obtained by method of true lengths of lines inclined to both planes.
FULL END VIEW HERE
AUXILIARY INCLINED PLANE
AUXILIARY PLAN
VERTICAL PLANE
ELEVATION
PLAN
HORIZONTAL PLANE
AUXILIARY VERTICAL PLANE
TRUE SHAPE OF FACE
AUXILIARY ELEVATION
SECTIONAL END VIEW ON S-N HERE
Parallel to S-N
AUXILIARY PLAN on Auxiliary Inclined Plane S-N
30°
45°



EXERCISE 10 — Use half of 22″ · 15″ paper — **PLATE 12**

Plate 12 shows the plan and elevation of a cross.

Draw, to a scale of full size, and in the positions shown :

(a) The given plan and elevation.

(b) The complete auxiliary elevation on the **AVP** at 45 to **VP**.

(c) The complete auxiliary plan on the **AIP** at 60 to **HP**.

EXERCISE 11 —
Use half 22" × 11" paper

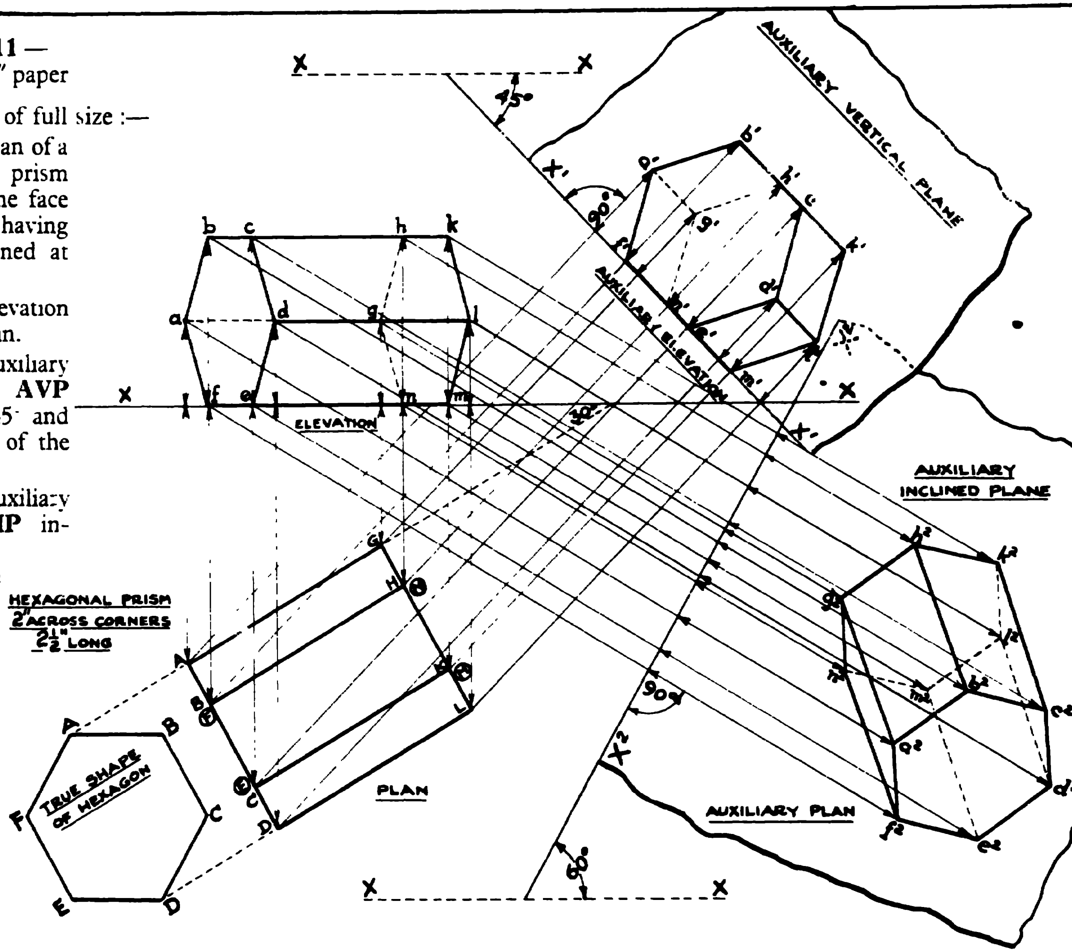
Draw, to a scale of full size :—

(a) The given plan of a hexagonal prism lying with one face on **HP** and having its axis inclined at 30° to **VP**.

(b) Project an elevation from the plan.

(c) Project an auxiliary elevation on **AVP** inclined at 45° and to the right of the elevation.

(d) Project an auxiliary plan on **AIP** inclined at 60° and to the right of the plan.



EXERCISE 12 — Use 22″ × 11″ paper — PLATE 14

Fig. 68 shows the plan of a cottage. The roof has hip rafters at one end and there is a chimney built up at the other gable end.

Draw, to a scale of $\frac{1}{8}''$ to a foot, and in the positions shown :—

(a) The given plan.

(b) The elevation.

(c) The end elevation looking from the right and placed alongside the plan.

(d) The auxiliary view on a line at 30° to the horizontal.

(e) The auxiliary view on a line at 45° to the horizontal.

(f) What is the actual length of the hip rafter ?

PLATE 14

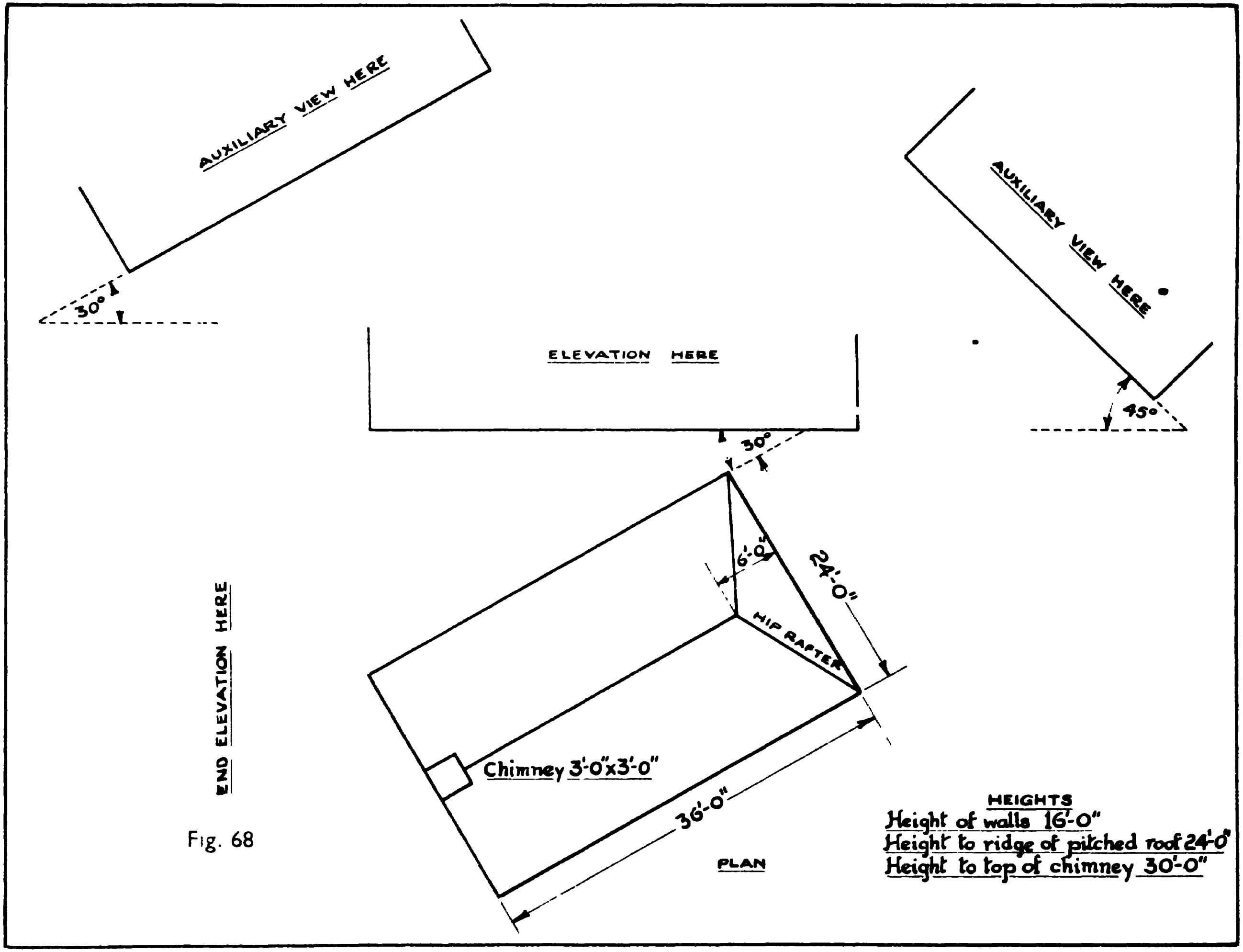


Fig. 68

EXERCISE 13 — Use 22″×11″ paper — PLATE 15

Fig. 69 shows the plan of an equilateral triangular prism placed centrally on a square prism.

Draw, to a scale of full size, and in the positions shown :—

(a) The given plan.
(b) The elevation.
(c) The sectional end view on **A - B.**
(d) The auxiliary view.

Fig. 70 shows the elevation of an equilateral triangular prism placed centrally against a square prism which is pierced by a square hole.

Draw, to a scale of full size, and in the positions shown :—

(a) The given elevation.
(b) The full end view.
(c) The sectional end view on **A - B.**
(d) The sectional plan on **B - C.**

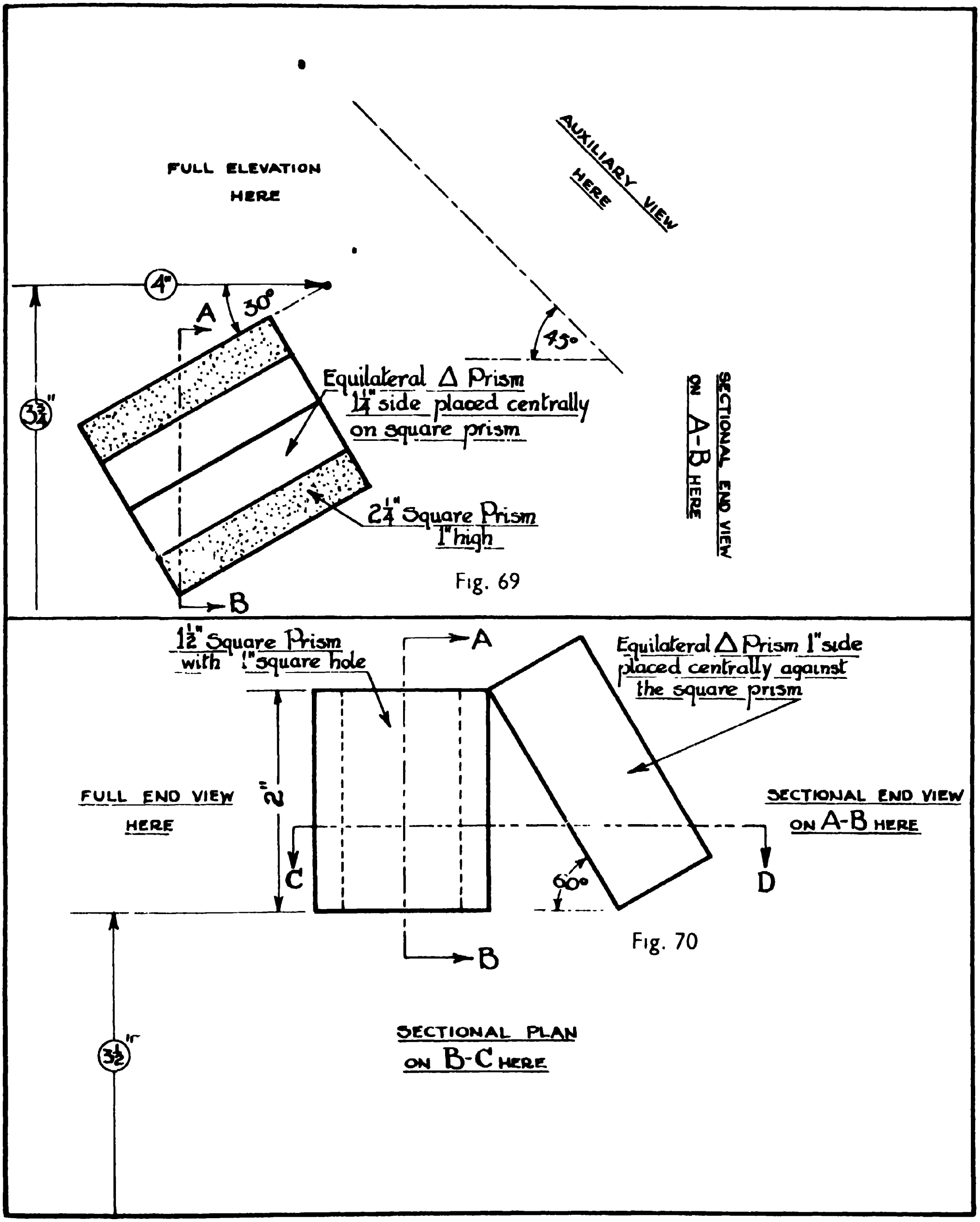

FULL ELEVATION HERE
AUXILIARY VIEW HERE
4"
30°
45°
3¾"
A
B
Equilateral Δ Prism 1¼" side placed centrally on square prism
2¼" Square Prism 1" high
SECTIONAL END VIEW ON A-B HERE
1½" Square Prism with 1" square hole
Equilateral Δ Prism 1" side placed centrally against the square prism
FULL END VIEW HERE
2"
60°
C
D
SECTIONAL END VIEW ON A-B HERE
SECTIONAL PLAN ON B-C HERE
3½"

Fig. 69

Fig. 70

EXERCISE 14 — Use 22″ × 15″ paper — PLATE 16

Fig. 71 shows sketch of a block having a sloping surface and pierced by a hexagonal hole.

Fig. 72 shows the plan and elevation of the block.

Draw, to a scale of full size, and in the positions shown :—

(a) The given plan and elevation.
(b) The true shape of the sloping surface.
(c) The auxiliary view.
(d) The auxiliary plan.
(e) The free-hand sketch of the block.

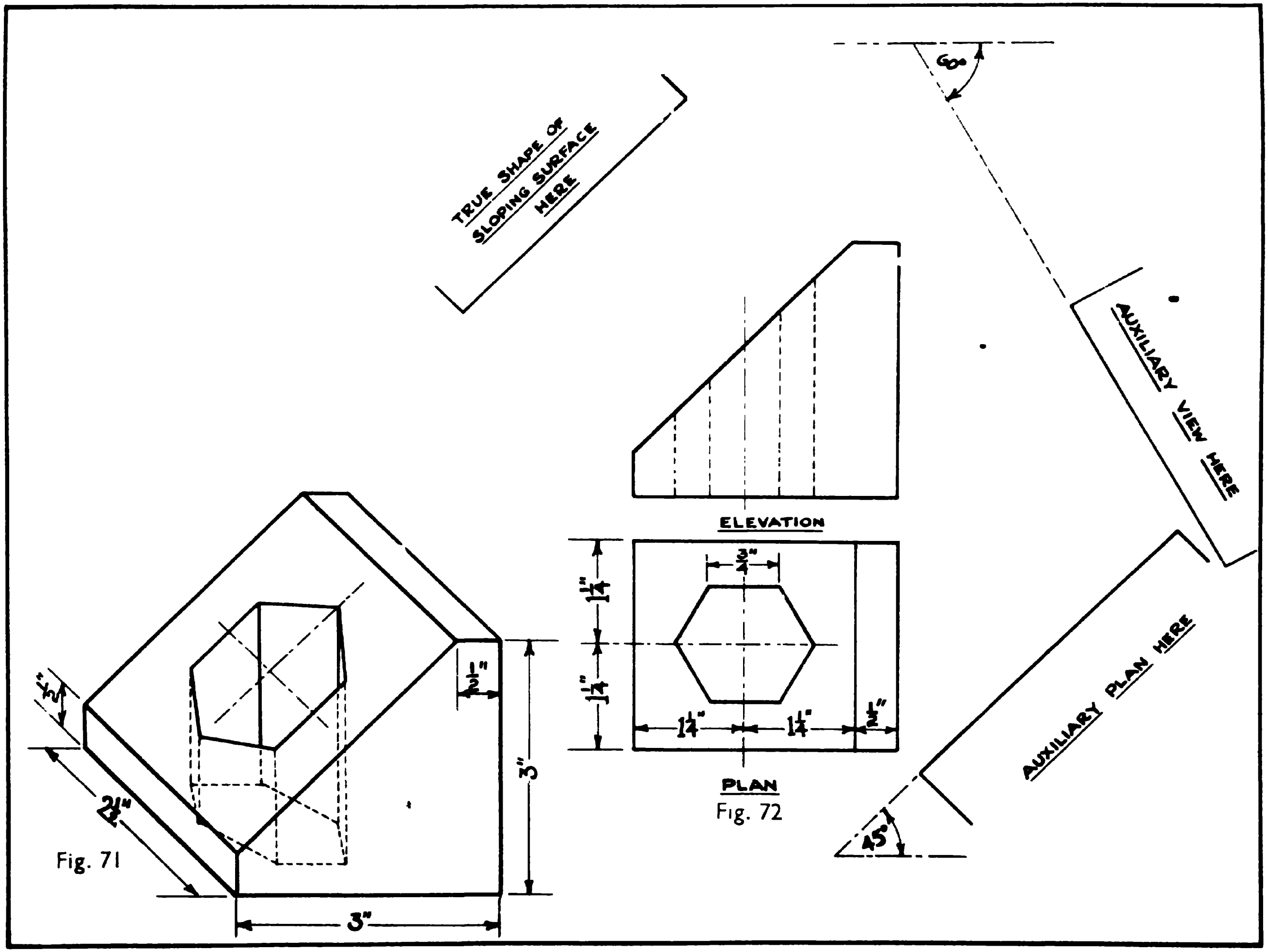

TRUE SHAPE OF
SLOPING SURFACE
HERE
60°
AUXILIARY VIEW HERE
AUXILIARY PLAN HERE
45°
ELEVATION
PLAN
3/4"
1 1/4"
1 1/4"
1 1/4"
1 1/4"
1/2"
1/2"
1/2"
3"
3"
2 1/4"

Fig. 71

Fig. 72

CHAPTER 3

OTHER TYPES OF TECHNICAL DRAWING (ISOMETRIC DRAWING — OBLIQUE DRAWING — PERSPECTIVE DRAWING — " EXPLODED " DRAWING — CO-ORDINATE DRAWING) — ARCHES — BRICKWORK — JOINTS IN CARPENTRY — ROOFS — BUILDING DETAILS

There are other types of technical drawing, besides that by orthographic projection, which are used to a limited extent in industry, viz. :

(1) **ISOMETRIC DRAWING**

(2) **OBLIQUE DRAWING**

(3) **PERSPECTIVE DRAWING**

(4) **" EXPLODED " DRAWING**

(5) **CO-ORDINATE DRAWING**

We shall now consider the advantages and the disadvantages of each type and compare them with the conventional method of orthographic projection.

ISOMETRIC DRAWING — PLATE 17

The principle of isometric drawing is based on the relative positions which the three adjacent sides of a cube take up in relation to the vertical plane. Fig. 73 shows the conventional plan and elevation of a cube standing in the **HP** with its edge **OA** perpendicular to **H.P.** Imagine the cube to be tilted forward until it is resting on the point **A** with the " solid " diagonal **OG** horizontal and perpendicular to the vertical plane (Fig. 74). Each of the upper faces is parallel to one of the other faces. The edges **OA, OC** and **OE** are referred to as the " *isometric axes* " and contain angles of 120°. Note that the faces of the cube have changed shape, e.g., compare the top face **OCDE** (Fig. 73) with that in Fig. 74. The edges of the cube have become foreshortened and by the same amount. In fact the projected lengths of these edges are in the ratio :—

$$\frac{\text{Projected length}}{\text{Actual length}} \quad \frac{\textbf{OA}\text{ (Fig. 74)}}{\textbf{OA}\text{ (Fig. 73)}} \quad \frac{\sqrt{2}}{\sqrt{3}} \quad .81 \text{ (taken as approx. } \tfrac{4}{5}\text{).}$$

Fig. 74 shows an isometric view of the cube with one of the isometric axis (**OA**) vertical and Fig. 75 shows a similar view with the same axis horizontal. Although convenient, and somewhat general in practice, it is not necessary to have one of the isometric axis vertical or horizontal ; it may be drawn in any direction to show the object to advantage ; but the angles between the axes must be 120°.

Figs. 76 and 77 show the various views of a brick when one of the axes is horizontal and one vertical.

PLATE 17

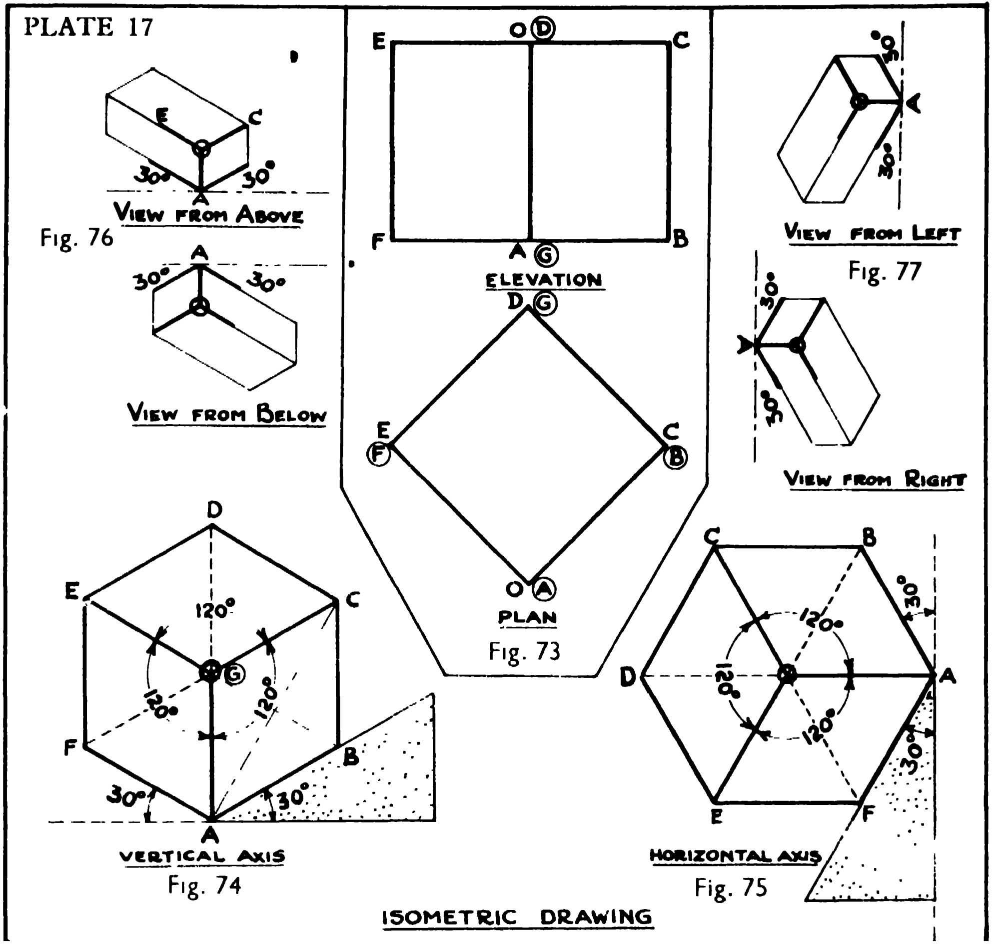


Fig. 76

Fig. 73

Fig. 77

Fig. 74

Fig. 75

To be a true drawing, the edges of the cube (Fig. 74) would require to be drawn approximately $\frac{3}{4}$ of their actual lengths and the drawing would be an **Isometric Projection** of the cube. Since all the lengths representing the edges have been reduced in the same ratio, $\frac{\sqrt{2}}{\sqrt{3}}$, it is more convenient in practice to draw all lengths, which are parallel to the isometric axes, to their **actual lengths** when the drawing is referred to as an **ISOMETRIC DRAWING**. This has the convenience that " isometric " lengths (lengths which are parallel to the isometric axes) can be measured directly from an isometric drawing. It is important to notice that " non-isometric " lengths are not actual lengths on an isometric drawing as will be seen by comparing the face diagonals **AC** and **OB** (Fig. 74).

Whereas the angles between the adjacent edges of a rectangular solid are right angles, these appear as acute or obtuse angles in an isometric drawing (**Figs. 76, 77**).

Isometric drawing is very convenient for the representation of rectangular objects, as it gives the appearance of solidity, and the three dimensions (length, breadth and height) may be obtained directly from such a single drawing. It is not so convenient for the showing of curves, circles or oblique lines, as these appear distorted, e.g., a circle on the face of a cube (Fig. 82, page 60) would appear as an ellipse. A knowledge of isometric drawing is useful in the making of rapid free-hand sketches.

Isometric drawing may be summed up as a type of technical drawing within limits, carried out with the minimum of work for the maximum of information. Whether making free-hand sketches or preparing isometric drawings, the following points should be kept in mind, viz.,

1. The object is depicted as cornerwise to the observer.
2. Lines (and surfaces) which are parallel on the object will be parallel on the sketch or drawing.
3. If the commencing axial line is vertical, then lines at right angles to it will be 30° to the horizontal (Fig. 74 PLATE 17). If the commencing axial line is horizontal, then lines at right angles to it will be 30° to the vertical (Fig. 75, PLATE 17).

EXERCISE 15 — Use 22″ × 15″ paper — PLATE 18

Fig 78 shows the isometric drawing of an angle plate.

Draw, to a scale of full size, in the positions shown :—

(a) The given view commencing with the corner **A-B**.

(b) The complete view, commencing with the corner **C-D**, as indicated in Fig. 79.

(c) The complete view as indicated by Fig. 80.

(d) The complete view as indicated by Fig. 81.

Which view do you think shows the features of the object to the best advantage?

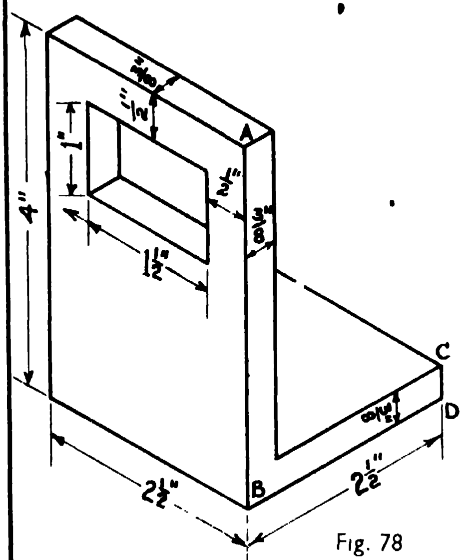


Fig. 78

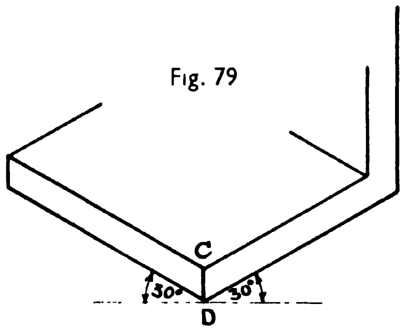


Fig. 79

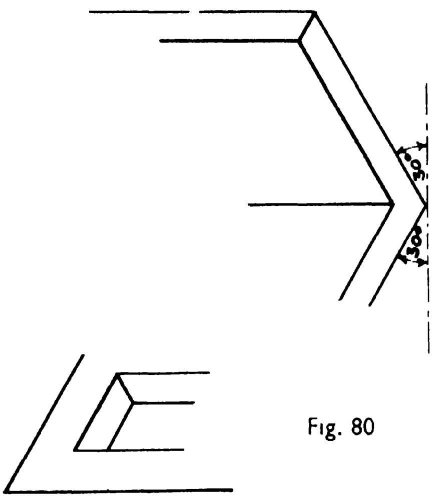


Fig. 80

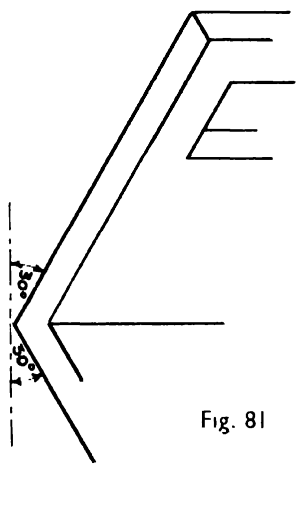
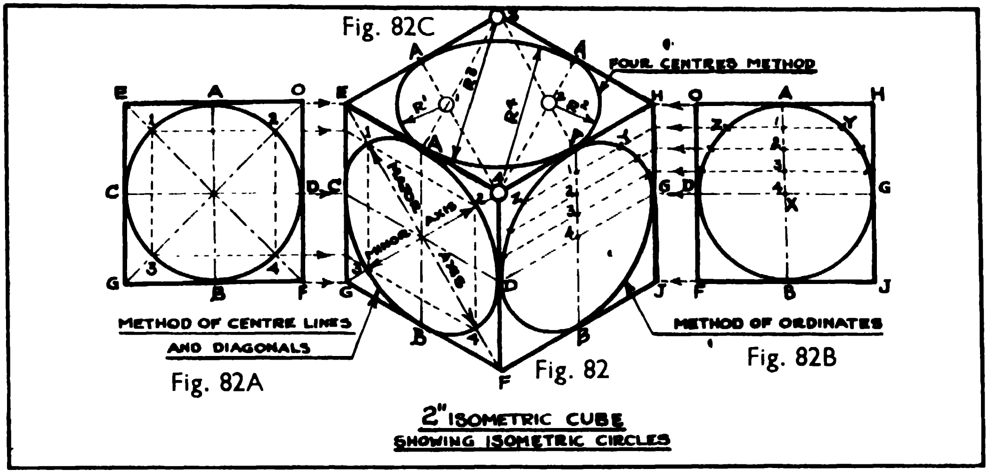


Fig. 81



THE CIRCLE IN ISOMETRIC DRAWING

Fig. 82 shows the isometric drawing of a cube which has a circle on its top face and similar circles on two adjacent vertical faces. The circle touches four edges of the cube in each case. A figure in the shape of an ellipse represents the circle in the drawings and it can be obtained quickly by three methods as follows:—

Method of Centre Lines and Diagonals Fig. 82A.

AB and **CD** are the vertical and horizontal diameters of the circle and **EF** and **OG** are diagonals.

Project **EAO, CD** and **GBF** on to the isometric face to obtain the diameters and diagonals in that view (Fig. 82).

A, B, C and **D** will be points on the ellipse.

Obtain the intermediate points 1, 2, 3, 4 (positions where circle and ellipse meet the diagonals).

Draw a smooth curve through the eight points and show the **major** and **minor** axes of the ellipse.

Conjugate Diameters: AB and **CD** are known as conjugate diameters because they are parallel to the tangents at the ends of the other diameters, i.e., **AB** is parallel to **EG** (and **OF**) and **CD** is parallel to **EO** (and **GF**).

Method of Ordinates Fig. 82B.

Draw the vertical and horizontal diameters **AB** and **DG** of the circle (Fig. 82B) and on the ellipse (Fig. 82).

Select a number of points on the half vertical diameter **AX**, say 1 - - - 4, and through these points draw the broken lines parallel to **DG** to meet the circumference of the circle as shown at **Z** and **Y** (Fig. 82B).

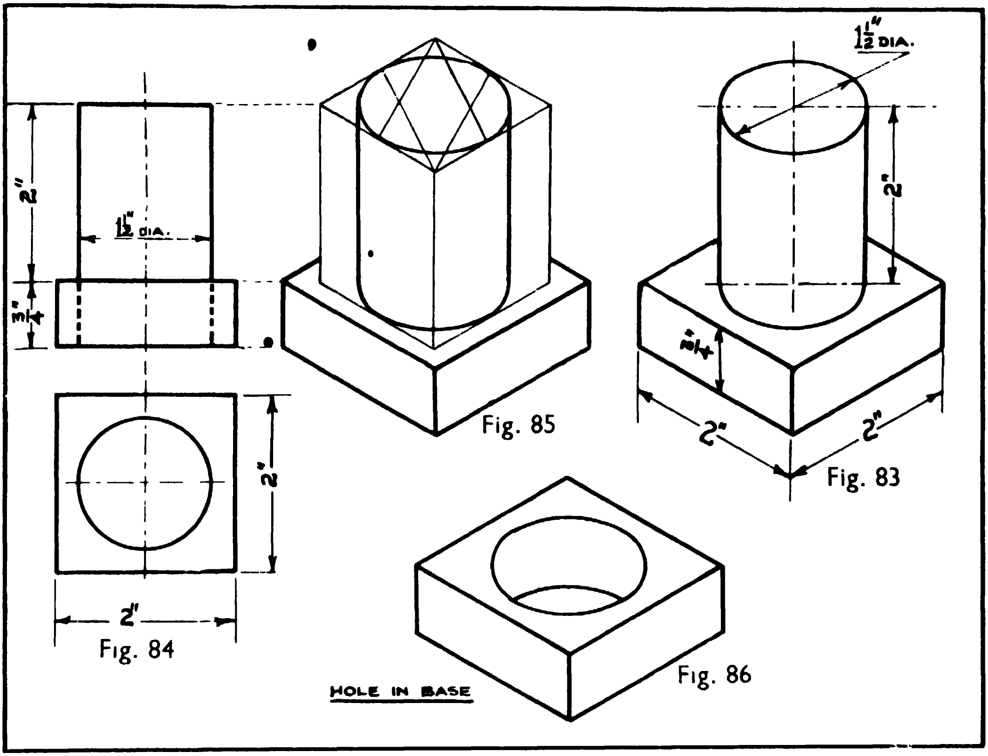


Fig. 84 Fig. 85 Fig. 83 Fig. 86

Project these lines on to the isometric face and set off their distances on each side of **AB** as shown at **Z** and **Y** (Fig. 82).

Draw a smooth curve through the nine points, giving the upper part of the ellipse. The lower half can be obtained by the same methods, or by the use of tracing paper.

Method of Four Centres Fig. 82C.

The circle is contained within a square (Fig. 82A or 82B) and is to be plotted on an isometric plane.

The mid points **A**, on each side of the rhombus, are points of tangency (Fig. 82C).

Erect true perpendiculars at each of these points (**A**) intersecting at $\mathbf{O^1}$ and $\mathbf{O^2}$. They also intersect at the opposite corners of the rhombus $\mathbf{O^3}$ and $\mathbf{O^4}$.

With centres $\mathbf{O^1}$, $\mathbf{O^2}$, $\mathbf{O^3}$, $\mathbf{O^4}$, and radii $\mathbf{R^1}$, $\mathbf{R^2}$, $\mathbf{R^3}$, $\mathbf{R^4}$ respectively, draw the four tangential arcs to form an approximate ellipse (Fig. 82C).

Similar construction can be used to draw circular arcs in isometric drawing.

Fig. 83 shows the sketch of a cylindrical plug fitted into a square base block as shown in the plan and elevation Fig. 84.

Draw an isometric view of this arrangement as shown in Fig. 85. Commence by drawing the circumscribing square prism around the cylinder. Draw an isometric view of the base showing the hole into which the cylinder fits, Fig. 86.

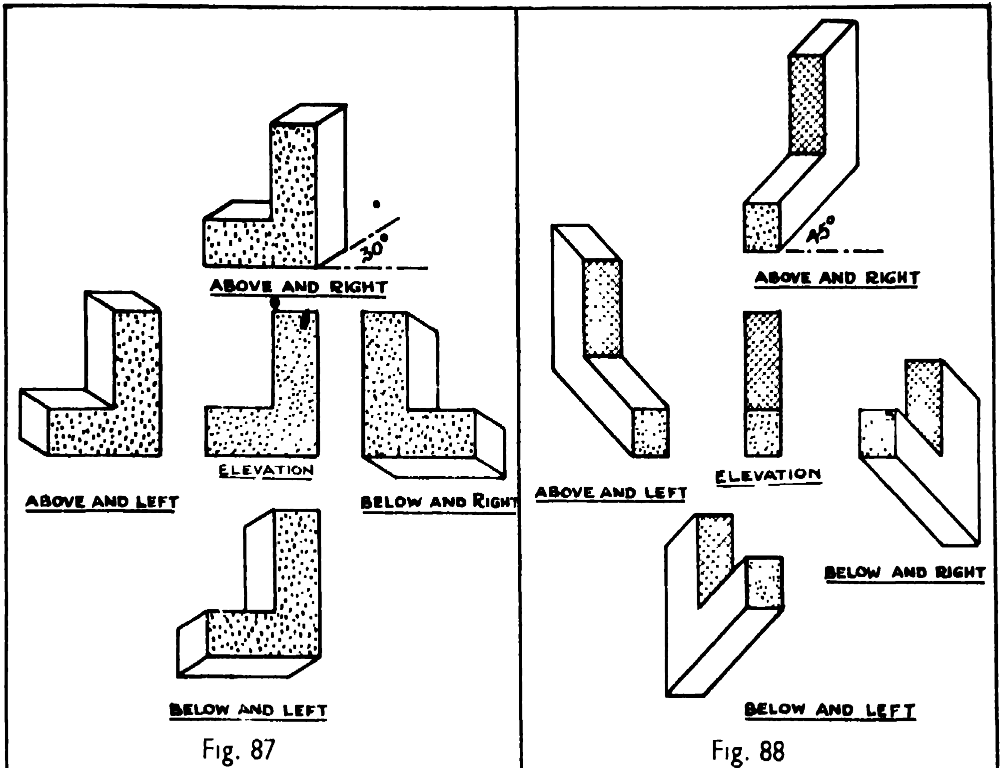
OBLIQUE DRAWING. PLATE 19

Oblique Drawing is similar to isometric drawing inasmuch as the three linear dimensions of a rectangular object may be suitably shown in one drawing. This type of technical drawing is easy to learn and to understand. While the object is presented *cornerwise* to the observer in isometric drawing, **oblique drawing** has the **great advantage** of having lines, which are parallel to the vertical plane, shown in **true orthographic projection** (i.e., their actual lengths are shown). Thus, there is always **one view** of the object in **true elevation.** Where a curve or circle appears in one view *only* that view may be selected as the orthographic elevation and the curve or circle will then appear true and not distorted as in isometric drawing.

That view of an object which will appear in true elevation having been selected, the **receding edges** may be drawn at **any convenient angle** in order to show other views as desired. Here again lines which are parallel in the object will be parallel in the oblique sketch or drawing. These receding lines may be drawn to the same fraction as that used for the elevation. Frequently, however, when the **receding edges** are longer than those forming the elevation, the drawing has an appearance of being **out of proportion** (due to our vision giving us the impression that receding parallel straight lines meet in the distance).

In order that an **oblique drawing** may have a **more realistic appearance** under such circumstances, all the **receding lines** may be drawn to a **suitable proportion** of the fraction used in drawing the elevation, usually that of **one half.** When this is done the oblique drawing must be carefully marked to this effect. While the oblique lines may be at any convenient angle, one of the *set square* angles (30°, 45° or 60°) is generally selected.

PLATE 19



OBLIQUE DRAWING
Showing various views and change of Elevation

Study Plate 19 carefully and recognise the benefit of selecting a suitable view for the true elevation, and by drawing the receding lines, in different directions, various views can be shown. By selecting the elevation shown in Fig. 87, very much better and more proportionate drawings of the other views are obtained. By selecting the small rectangular elevation shown in Fig. 88, the other views make the drawings appear out of proportion because the receding lines are longer than those forming the elevation. This could be improved by drawing all receding lines to a reduced proportion, say half, of their actual lengths.

Fig. 89 shows the plan and elevation of a square block with a hole through the centre of it. If the face (3″ × ¾″) Fig. 90 is selected for the elevation, the circle representing the hole will appear as an ellipse. It is more convenient to use a face which will show a true circle (Fig. 91) when the elevation and the drawing will have better appearance and proportion. The centre for the circle on the back face is obtained by making the distance **O-O**[1] equal to the thickness (¾″).

EXERCISE 16 — Use 22″ × 15″ paper — **PLATE 20**

Draw, to a scale of full size, Figs 89, 90, 91.

Fig. 92 shows the plan and elevation of part of a " dog " coupling.

(a) Draw, to a scale of full size, the given views.

(b) Complete the oblique view.

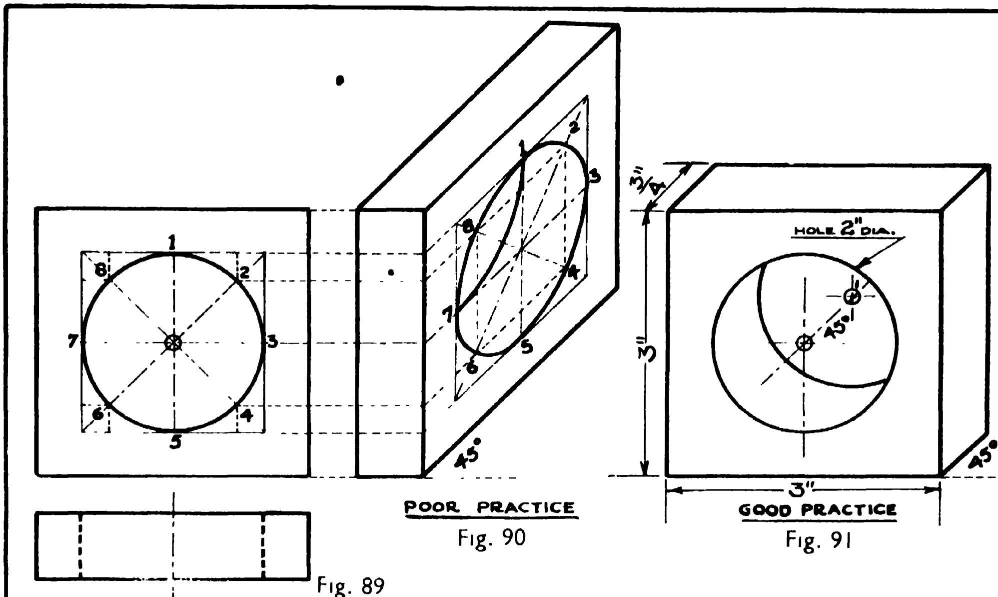


Fig. 89

Fig. 90

Fig. 91

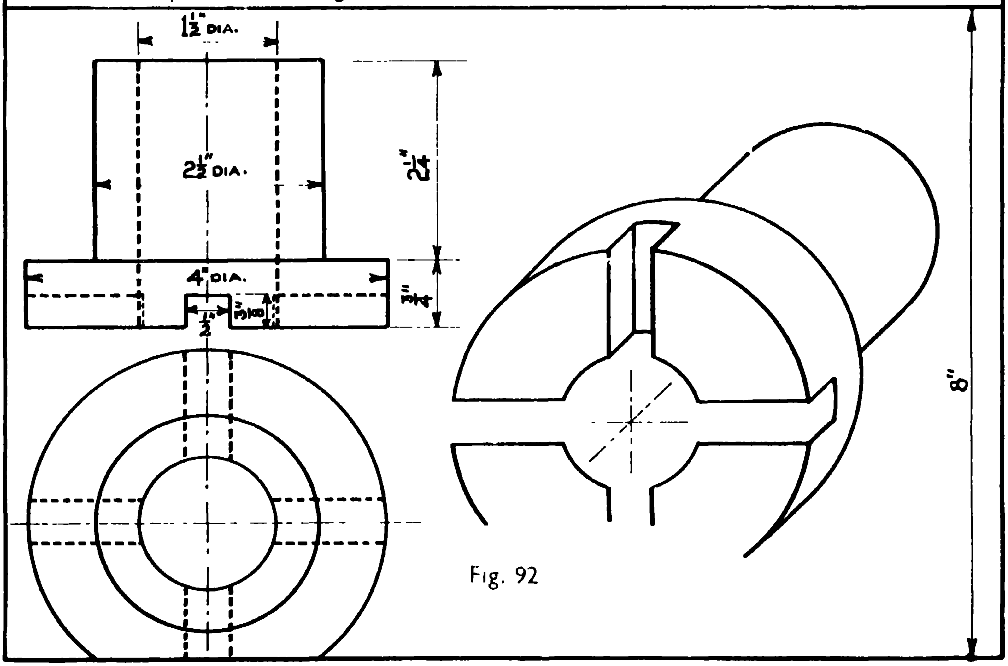


Fig. 92

EXERCISE 17 — Use half 22″ × 11″ paper — PLATE 21

Fig. 93 shows the elevation and end view of an angled bracket.

Draw, to a scale of full size, the given views using the " ordinate " method to obtain the ellipses.

Fig. 93A shows a method, frequently used in practice, whereby the actual shape of the sloping face (showing the hole) is projected as an auxiliary view on AB.

Complete the two oblique views of the bracket, Fig. 94, using the " four centre " method to obtain the ellipses ; make the receding lines $\frac{3}{4}$ full size in each case.

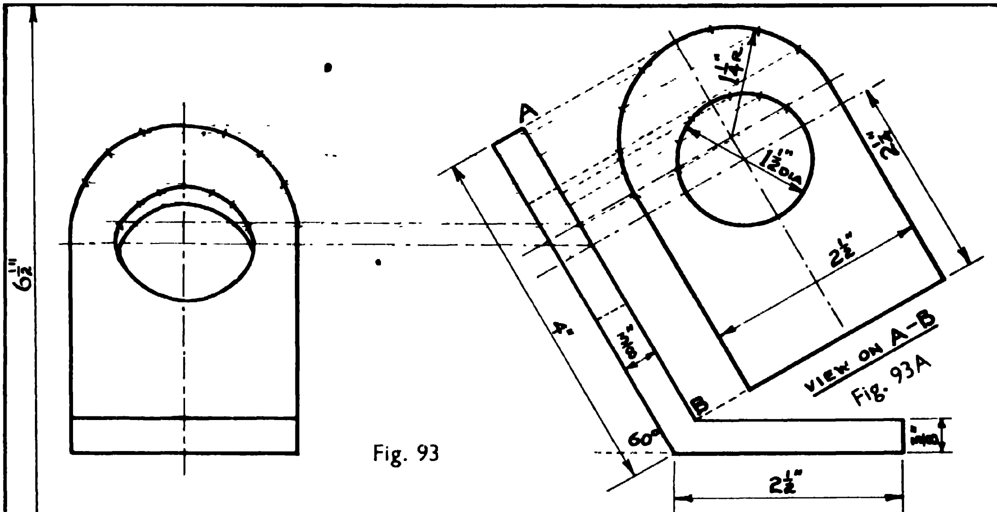
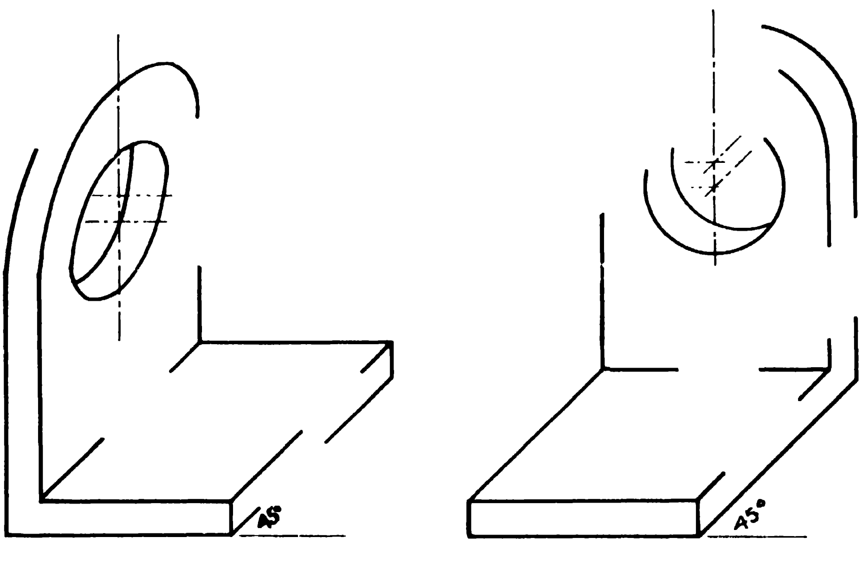


Fig. 93

Fig. 93A

ORTHOGRAPHIC DRAWING



OBLIQUE VIEWS

Fig. 94

EXERCISE 18 — Use half 22″ × 15″ paper — **PLATE 22**

Fig. 95 shows the front view of a $1\frac{1}{2}''$ hexagonal nut.

(a) Draw, to a scale of full size, the given view.
(b) The isometric view Fig. 96 to the same dimensions.
(c) The oblique view Fig. 97 to the same dimensions.

Fig. 98 shows the elevation and plan of a hexagonal plug.

(a) Draw, to a scale of full size, the given views.
(b) Complete the isometric view Fig. 99 to the same dimensions.
(c) Complete the oblique view Fig. 100 to the same dimensions.

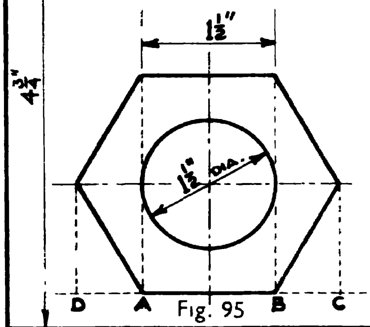
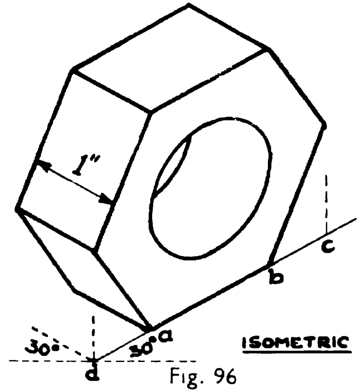
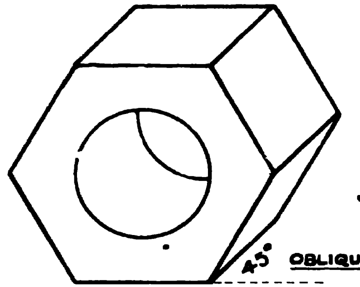


Fig. 95



ISOMETRIC

Fig. 96



OBLIQUE

Fig. 97

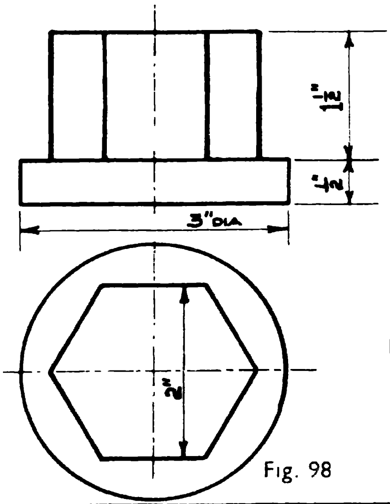


Fig. 98

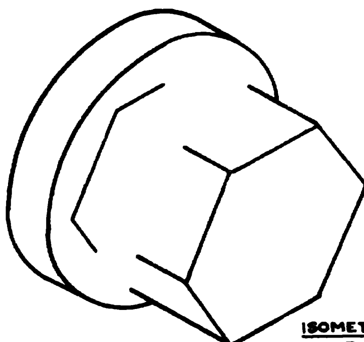

ISOMETRIC VIEW.

Fig. 99

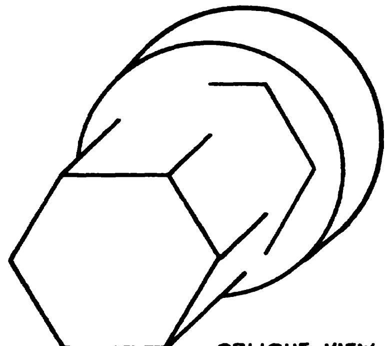
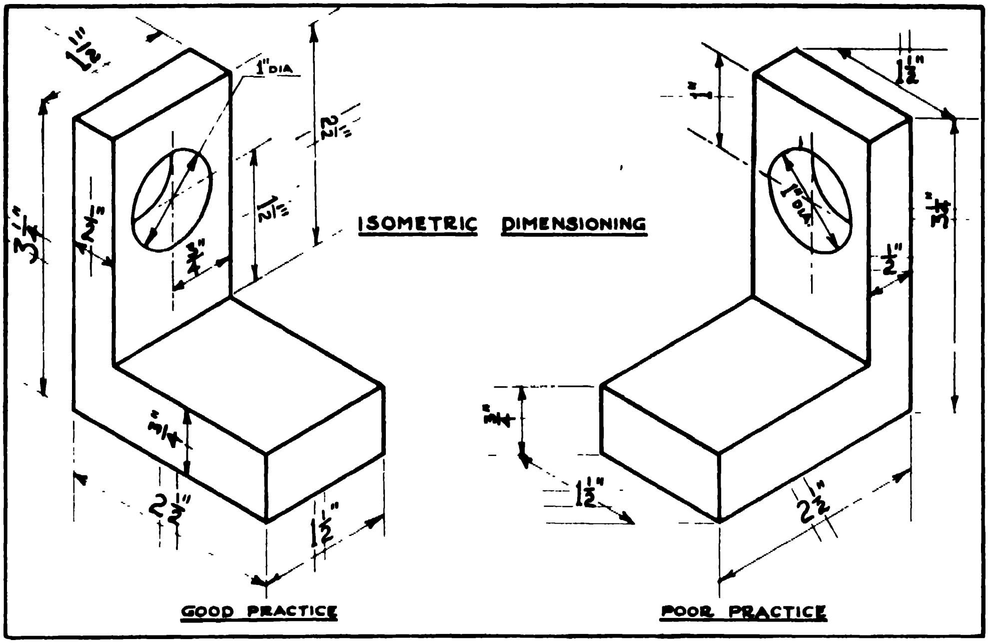

OBLIQUE VIEW

Fig. 100



DIMENSIONING OF ISOMETRIC AND OBLIQUE DRAWINGS

(a) Dimension and extension lines are drawn parallel to their respective axes, i.e., to the isometric axes or to the axes of the oblique view.

(b) Dimension and extension lines should be drawn in the planes, or surfaces, to which they refer.

(c) Dimensions can be placed on the object ; but only on visible surfaces.

(d) Wherever possible it is better to show horizontal dimensions below the object.

(e) Centre lines, fractions and reference letters should be parallel to the axes ; but descriptive notes are generally lettered on the horizontal and near to the parts to which they refer.

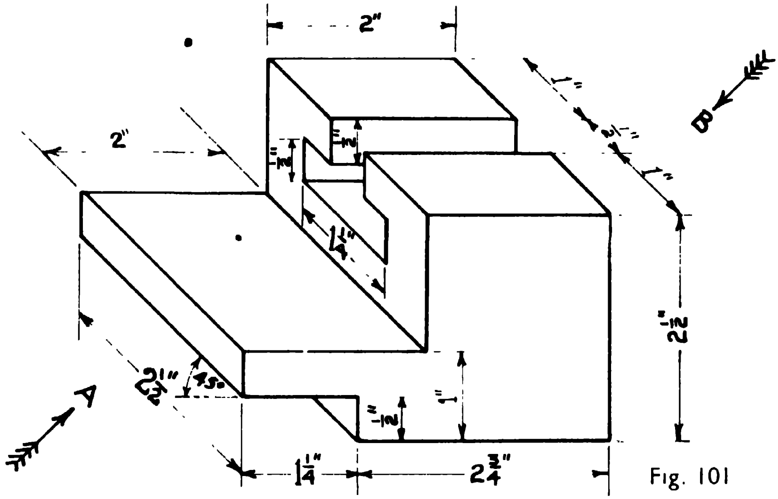


Fig. 101

EXERCISE 19 Use half 22" × 15" paper

Fig 101 shows the oblique view of a slotted casting

Draw, to a scale of full size, in the positions shown :—

(a) The given view.
(b) The complete view, looking in the direction of the arrow A, as indicated in Fig. 102.
(c) The complete view, looking in the direction of the arrow B, as indicated in Fig. 103. Make the receding lines $\frac{3}{4}$ full size.

Which view do you think shows the features of the object to the best advantage?

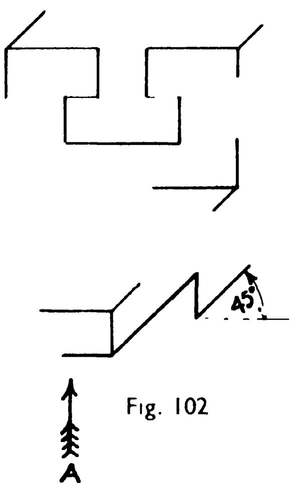


Fig. 102

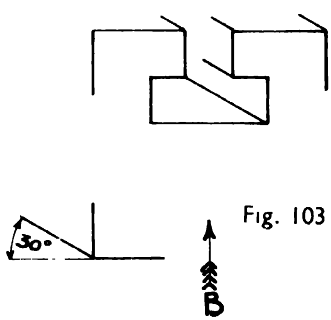


Fig. 103

PERSPECTIVE DRAWING

In an **Orthographic**, an **Isometric** or an **Oblique** Drawing of an object the **linear dimensions** may be taken from the drawing. In **Perspective** Drawing this is **not the case** as this type of technical drawing deals solely with **appearances**, i.e., the appearance of an object to the eye of the observer. **Orthographic, isometric** and **oblique** drawings are prepared by **parallel** projection whereas **perspective drawing** is carried out by **radial** projection from a point, usually considered as the eye of the observer. It is as if rays of light carried with them the impression of the various points on the object from which they emanate. The angle between the extremes of these radial lines, with the eye as vertex, is usually taken as 60°. Thus the further away an object is, the smaller does it appear. The pupil should prove this for himself by looking at some object through a window. He should stand away from the window as far as possible, then move to within a few feet of it and notice the change in the appearance of the object. Similarly, when viewed through the window of a railway carriage, objects nearest the window pass out of vision more quickly than those in the distance, because the former are cutting the arms of the " radial " angle nearer the vertex (eye). Although perspective drawing is an exact science, it has little practical value so far as technical drawing applied to construction is concerned.

Fig. 104 shows the **L**-shaped figure in a certain position, and viewed from a point which is $\mathbf{d}_1$ above HP and $\mathbf{d}_2$ from VP. A simple method of finding the perspective of an object is as follows :—

Draw the orthographic elevation and plan (Fig. 104). Fix the distance of the eye point above HP and away from VP. Join all the points of the object to these view points (Fig. 104). You should notice that the rays from *unseen* points may coincide with those from *seen* points. The line of the picture plane is then drawn. This picture plane corresponds to the window in the simple experiment just described, with this difference, that the window glass was stationary and your " eye-point " adjustable, whereas here the " eye-point " is stationary and the picture plane can be adjustable. The appearance of the object is that shown on the picture plane. An " auxiliary plane " is drawn, parallel to the picture plane, on the other side of the plan and elevation to assist in the perspective drawing.

Consider the rays $\mathbf{R}_1$, $\mathbf{R}_2$, intersected by the picture plane at $\mathbf{r}_1$, $\mathbf{r}_2$ in the elevation and $\mathbf{r}_1$, $\mathbf{r}_2$, in the plan (Fig. 104). Project these points over to the auxiliary plane. With centre at the point of intersection between the auxiliary plane

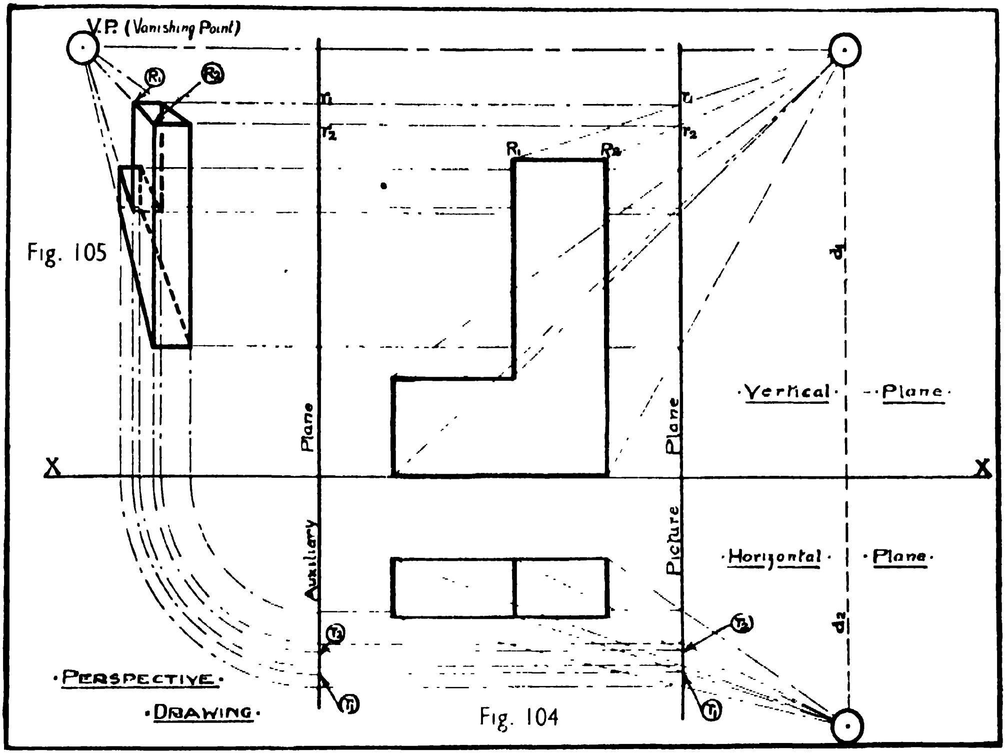


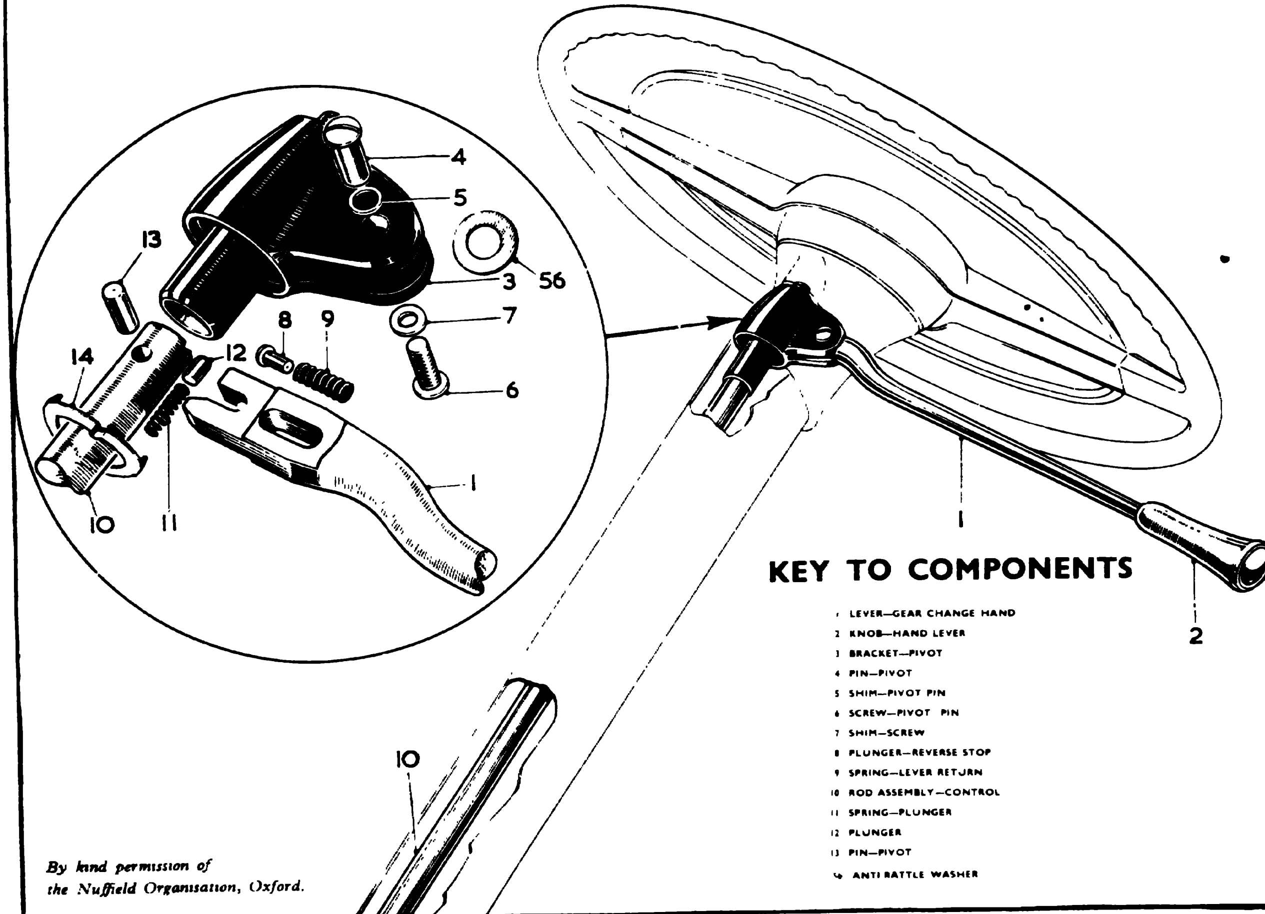
Fig. 105

Fig. 104

and the **XX** line and radius to $\mathbf{r}_1$ and $\mathbf{r}_2$ carry the points $\mathbf{r}_1$, $\mathbf{r}_2$, round through 90° to the **XX** line. Continue the projectors until they meet those from $\mathbf{r}_1$, $\mathbf{r}_2$, in the points R_1 - R_2. The line R_1 - R_2, gives the perspective view of the line $\mathbf{R}_1$ - $\mathbf{R}_2$ when viewed from the given view point. Other points on the object are traced out in the same way and the perspective drawing completed as in Fig. 105. The lines forming the perspective drawing, if produced, meet in a point, called the vanishing point. The drawing shown in Fig. 105 has only one vanishing point. The fact will now be obvious that it is impossible to obtain true linear and angular particulars of the object from this perspective drawing. It is the view of an object as seen on a picture plane when viewed from the "eye-point" selected. An architect makes use of perspective drawings to show the general appearance of a building to clients who are not familiar with reading the plans and elevations as prepared for the builders.

"EXPLODED" DRAWING — PLATE 24

"Exploded" drawing is more related to the realm of technical art "illustration" than to pure technical drawing. It is ideal, for conveying technical information in a simple and lucid manner. The drawing is done in sketch form, generally without dimensions, so that it is unsuitable for manufacturing purposes. The idea is that several component parts have been "exploded" from a technical unit, to indicate the order of their assembly within the unit. Plate 24 shows the hand lever mechanism, situated near the steering wheel of a motor car, used to operate the speed change wheels in the gear box. Such a drawing would be of great assistance to those involved in the assembly, maintenance and servicing of such equipment. An owner-driver, who was technically minded and desired to understand and to carry out such work, would be able to "read" instructions conveyed to him without the necessity of having a wide technical knowledge and vocabulary. Accordingly, "exploded" drawings are used frequently in handbooks, e.g., motor cars, washing machines, vacuum cleaners, etc., to assist in maintenance and minor adjustments.



KEY TO COMPONENTS

1 LEVER—GEAR CHANGE HAND
2 KNOB—HAND LEVER
3 BRACKET—PIVOT
4 PIN—PIVOT
5 SHIM—PIVOT PIN
6 SCREW—PIVOT PIN
7 SHIM—SCREW
8 PLUNGER—REVERSE STOP
9 SPRING—LEVER RETURN
10 ROD ASSEMBLY—CONTROL
11 SPRING—PLUNGER
12 PLUNGER
13 PIN—PIVOT
14 ANTI RATTLE WASHER

By kind permission of the Nuffield Organisation, Oxford.

"EXPLODED" DRAWING

ASSESSMENT OF VARIOUS TYPES OF TECHNICAL DRAWING

Isometric Drawing and **Oblique Drawing** are limited in their applications as they **never show all dimensions and angles** accurately. Both are quite suitable for making technical drawings of simple rectangular objects with little curved detail.

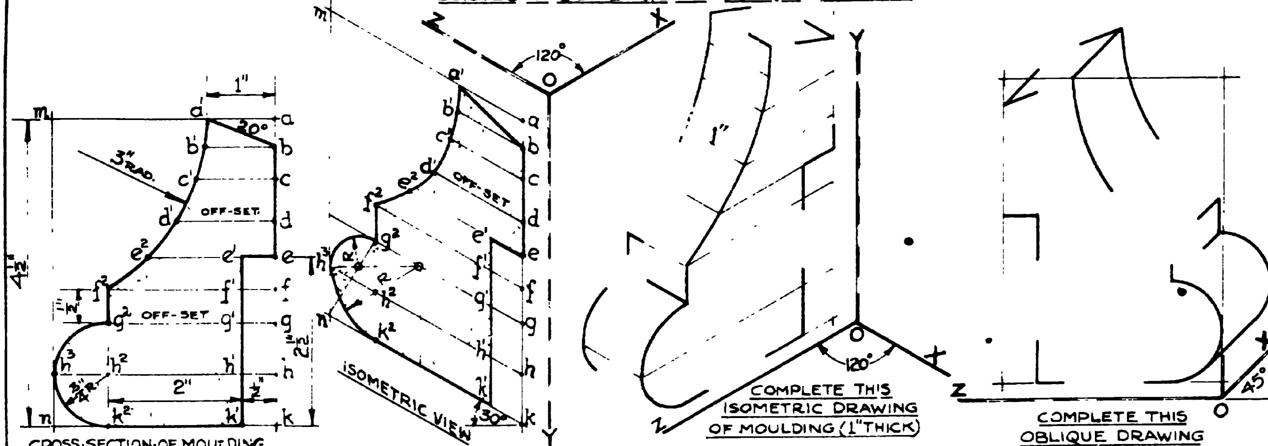
Perspective Drawing deals with **appearance** only and does not provide the necessary information for practical purposes. Not everyone, who contemplates building a house, can comprehend fully the technical drawings which the architect has to prepare for the builder ; but all can admire, or criticise, a perspective drawing according to their own ideas. Such a drawing would obviously show a new house to best advantage from the point of view of appearance.

" Exploded " Drawing, like Perspective, **lacks technical detail** for manufacturing purposes ; but it is extremely helpful for conveying information about the components, purpose and usefulness of a complete unit.

Orthographic Drawing is universal in its application to constructional details and manufacturing processes, since it provides all linear, angular and other necessary information for the work in hand.

Co-ordinate Drawing replaces the conventional system of dimensioning a drawing by replacing it with a series of reference points. This enables the information on the drawing to be transformed, so that it can be reproduced on a magnetic tape similar to that used for speech recording. Further details of this system are given on page 231

·CURVES·IN·ISOMETRIC·AND·OBLIQUE·DRAWING



EXERCISE. — [illegible] 22 [illegible] 15 paper. The cross section outline of a moulding is shown [illegible] by the rectangle **a m n k** and is divided by a number of [illegible] off-sets **a a, b b, c c -----** **h, h', h h³**

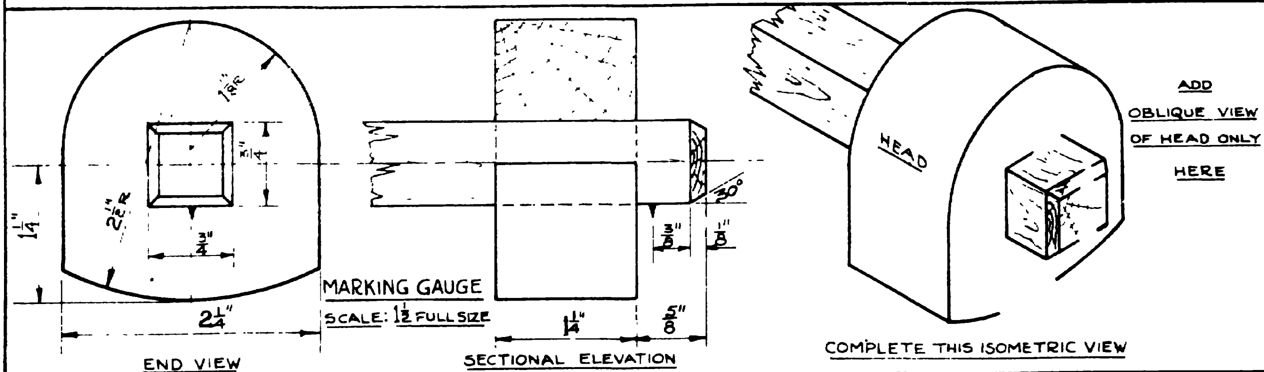
Draw the isometric axes **OX, OY, OZ,** [illegible] of the rectangle parallel to the [illegible] **OY** and **OZ**.

Mark off the [illegible] **-- h, k,** and through them draw [illegible] **OZ**.

Transfer the "off-sets" on the cross section to their respective positions in the isometric view ("Method of Ordinates", Fig. 82B, page 60).

The half ellipse, representing the semi-circle, is drawn by the "Four Centres Method" Fig. 82C, page 61, and the curve, **a, b' --- f²,** is drawn by "French" curve or by drawing a smooth curve through the "off-set" points.

Complete the isometric and oblique drawings and proceed to the exercise on the marking gauge.



ARCHES — PLATE 25*

The purpose of an arch is to support a load over an open space, as in windows, doors, roofs, and bridges. The arch structure is formed of wedge-shaped blocks, built according to some curve, and arranged to support each other. The arch serves to transmit the pressure, due to the super load, on to the actual supports, through the stones or bricks of which the arch is composed. A straight, horizontal, and one-unit support, bridging an opening, is called a *beam* or *lintel.*

The method of striking the curve of a few of the common arches is shown in this plate.

The Semi-Circular Arch, Fig. 107. The radius of the arch is equal to the rise.

The Segmental Arch, Fig. 108. The arch is the arc of a circle which passes through the three points, **A**, **B**, **C**. The centre is at the point where the perpendicular bisector of **AB** meets the vertical centre line through **B**.

The Equilateral Arch, Fig. 109. The arch is formed by the two arcs of a circle, whose centres are the springing points and whose radius is equal to the span.

The Three-Centred Arch, Fig. 110. This arch is sometimes referred to as an *elliptical* arch; but it is not elliptical. The shaping of the voussoirs for a true elliptical arch would involve an amount of labour altogether out of proportion to the benefit to be derived from a true elliptical curve. The arch, which may have its span and rise fixed, is struck from three centres C_1, C_2, C_3. Equal distances are measured from **A**, **B**, and **E**, giving the points C_1, C_2, and **D**. C_1 and C_2 are centres. The third centre (C_3) is the point where the perpendicular bisector of DC_2 meets the vertical centre line through **E**.

The Lancet Arch, Fig. 111. The centres for this arch lie on the springing line produced. Where the perpendicular bisector of **BC** meets the springing line produced is a " centre."

EXERCISE 20 — Use half 22″ × 15″ paper — PLATE 25

Draw, to a scale of twice that shown on the plate, the various outlines of the arches and insert all information.

Use the dividers carefully to avoid defacing the page.

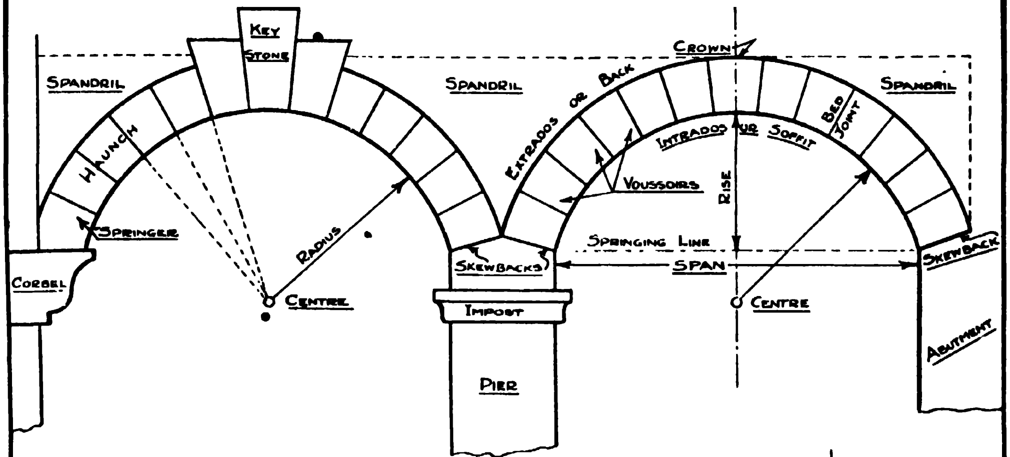


Fig. 106

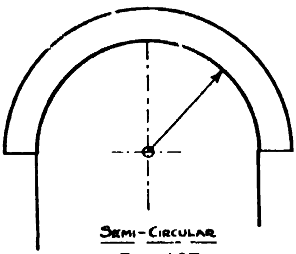


Fig. 107

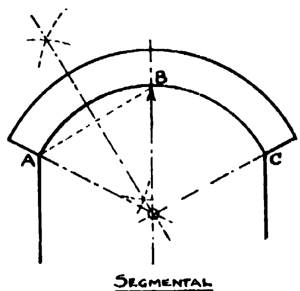


Fig. 108

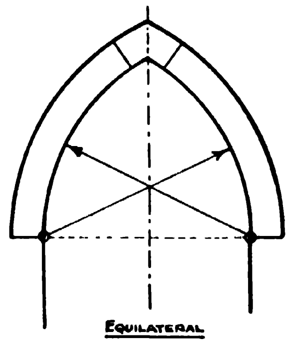


Fig. 109

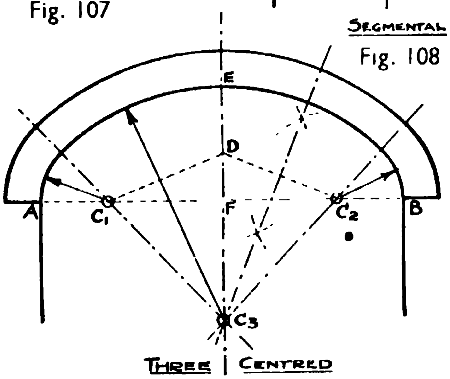


Fig. 110

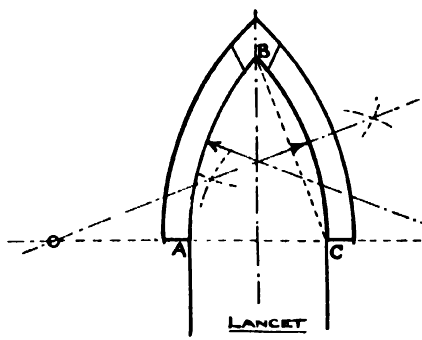


Fig. 111

BRICKWORK. PLATE 26

The practice of laying bricks in lime or cement mortar in order that they will form a rigid mass for the purpose required is called brickwork. The approximate size of a common brick is 9″ long × 4½″ wide × 3″ thick. The width is one half, and the thickness one-third, of the length. The width is a convenient grip for the hand of a man, while the half portion to the length assists in the systematic laying of the bricks. They are *never* laid with the 3″ face in the mortar, so that the thickness of brick walls will always be in multiples of 4½″.

English Bond.—This consists of a course of stretchers and a course of headers alternately on the face of the wall (Fig. 112).

Flemish Bond.—This consists of a stretcher and a header alternately in the same course on the face of the wall (Fig. 113).

N.B.—*Model bricks, made in wood, about 3″ × 1½″ × 1″ are exceedingly helpful in the understanding of brick bonds.*

EXERCISE 21 — Use 22″ × 15″ paper — PLATE 26

Construct a scale of 1″ to a foot and draw the corners of a 9″ wall built in English and Flemish bonds. Add the orthographic plans of two successive courses; insert dimensions and technical information (Figs. 112, 113).

TECHNICAL INFORMATION

Brick.—Fig. 114 shows a dimensioned isometric sketch of a brick.

Frog.—This is the recessed part on the top and under faces of a brick (Fig. 114). The principal function of the frog is to provide a " *key* " for the mortar and so bind the " courses " of brick more securely. Imagine the difficulty you would have in trying to drive a single brick out of a wall on account of its being " *keyed* " to the "courses" immediately above and below. Incidentally the frog gives lightness to the brick. Frogs are only obtained on machine and handmade bricks ; those which are "wire-cut" resemble rectangular prisms and are smooth on all faces.

Course.—This is a row, or layer, of bricks between two horizontal mortar joints (Fig. 112).

Bond.—This is the systematic arrangement of the bricks in a wall so that the vertical joints are not in line with each other in the courses immediately above and below. Fig. 115 shows bonding and its result as regards the distribution of a load **W** over the foundations of the wall.

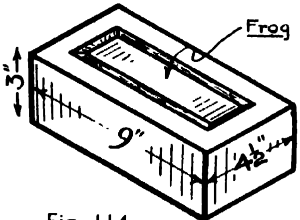


Fig 114

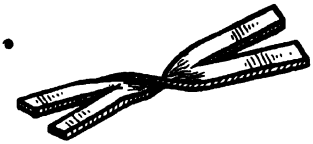


Fig. 116

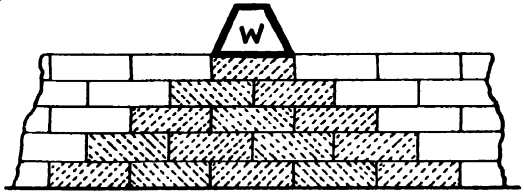


Fig. 115

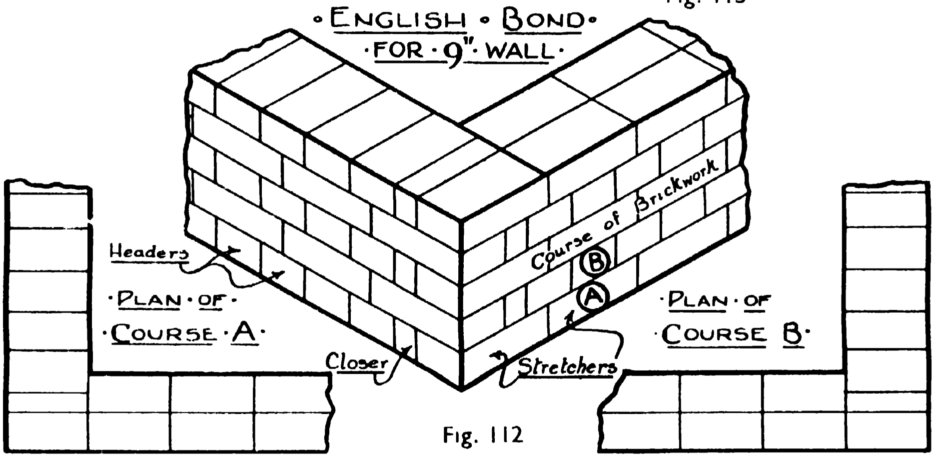


Fig. 112

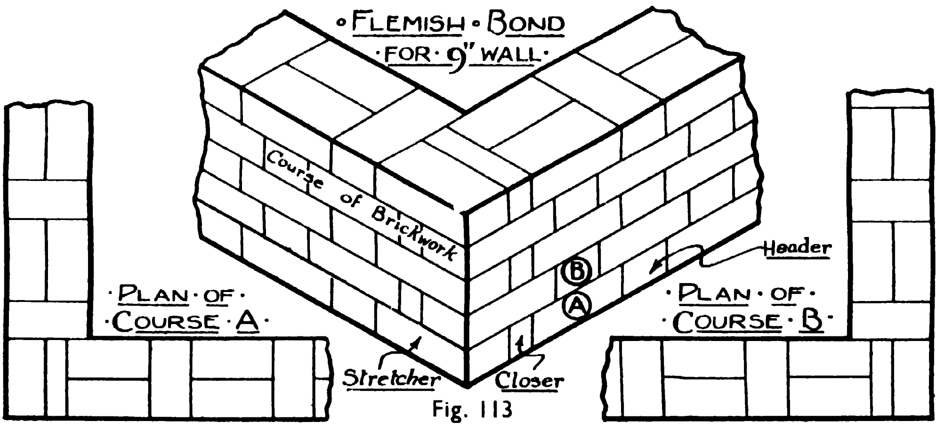


Fig. 113

Mortar.—This is a mixture of lime **or** cement, and sand, applied in a plastic state and used to bind the bricks together.

Stretchers.—These are bricks laid with their 9″ length on the face of the wall (Fig. 112).

Headers.—These are bricks laid with their $4\frac{1}{2}$″ width on the face of the wall (Fig. 112).

Closers.—These are bricks the same length and thickness as ordinary bricks, but only half the width. They are placed next to the first corner header to give lap and to break bond (Fig. 112).

Iron Wall Ties.—These are pieces of twisted galvanised iron about 9″ long × 2″ wide × $\frac{1}{8}$″ thick (Fig. 116). They are placed every three feet of length (or 3 to the square yard of wall area) to tie the outer to the inner wall in "*hollow*" wall construction. The purpose of the peculiar twist is to prevent moisture creeping, by means of the tie, across the "*hollow*" to the inner wall. Any moisture would be carried round the twist and, on reaching the lowest point, drop into the hollow space between the two walls (Plate 30—Page 91).

COMMON JOINTS USED IN CARPENTRY

An early requisite in the study of building construction is a knowledge of the different methods employed in the joining of two pieces of timber together. Joints may be classified under three principal groups, *viz.*,

(1) **Bearing Joints.**—Notching, cogging, halving, housing, bridle and mortise and tenon.

(2) **Oblique Shoulder Joints,**—Mitre (as at the corner of a picture frame), oblique tenon and bridle.

(3) **Lengthening Joints.**—Lapping, fishing and scarfing.

The Glued Joint. This is fundamentally a butt joint. The strength of the joint depends on the extent the glue penetrates into the wood. Hence open fibred timber such as pine, redwood, etc., will hold better at a glued joint than will close grained or hardwood such as teak, walnut, rosewood, etc. The glued joint is much used in the process of "*facing*," or veneering, a cheap soft wood with a thin layer of hard expensive wood at places exposed to view. This "*facing*" is then polished giving the appearance of a solid article in the better quality wood. Circular work is generally built up with glued joints, *e.g.*, corners of furniture and patterns in pattern-making.

Fig. 117

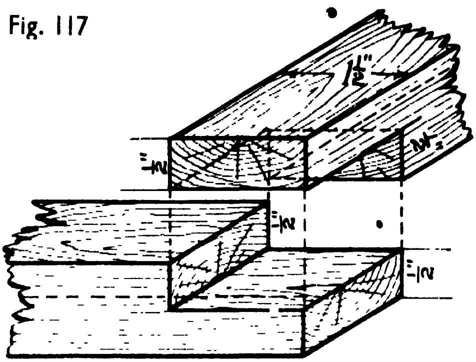


Fig. 118

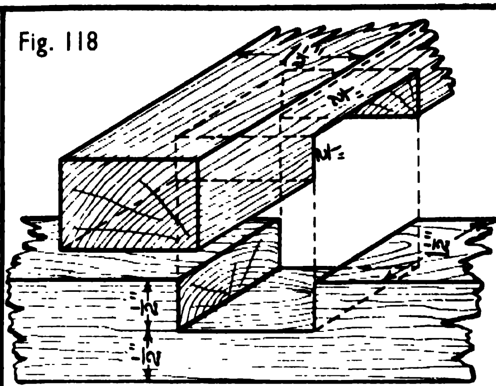


Fig. 119

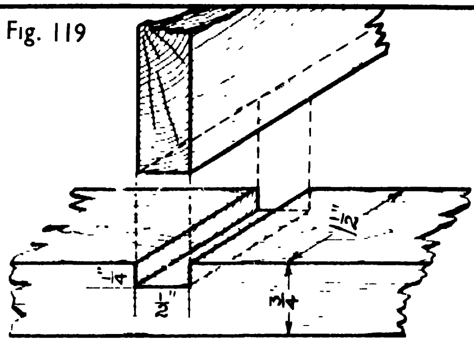
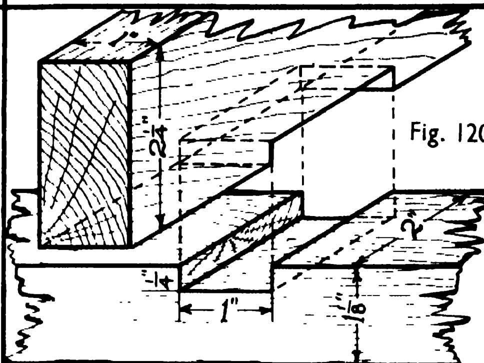


Fig. 120



The Simple Halving Joint. (Fig. 117). This joint is used in the formation of a right angle. The two members are halved and shouldered on opposite sides and the joint put together direct off the saw. The rough faces materially assist in the efficiency of the joint as the fibres "*bite*" together when glued or fastened with screws or dowel pins to resist the shear stress.

The Half-Lap Joint. (Fig. 118). This is a variation of the simple halving joint where the timbers are carried through. The cross members remain "*flush*" or in the same plane. When this joint is well made there is little necessity for fastening with screws.

The Housing Joint. (Fig. 119). This joint consists in the fitting of the entire end or thickness of one piece of wood into a groove, or trench, in another. It is used in the formation of dividing partitions as inside drawers and bookcase shelving.

The Notched Joint. (Fig. 120). This joint is used where a tie or fastening is required without materially weakening the timbers to any great extent, *e.g.*, where joists cross one another on a floor, where purlins cross the rafters on a roof, where roof ties rest on a wallplate, etc.

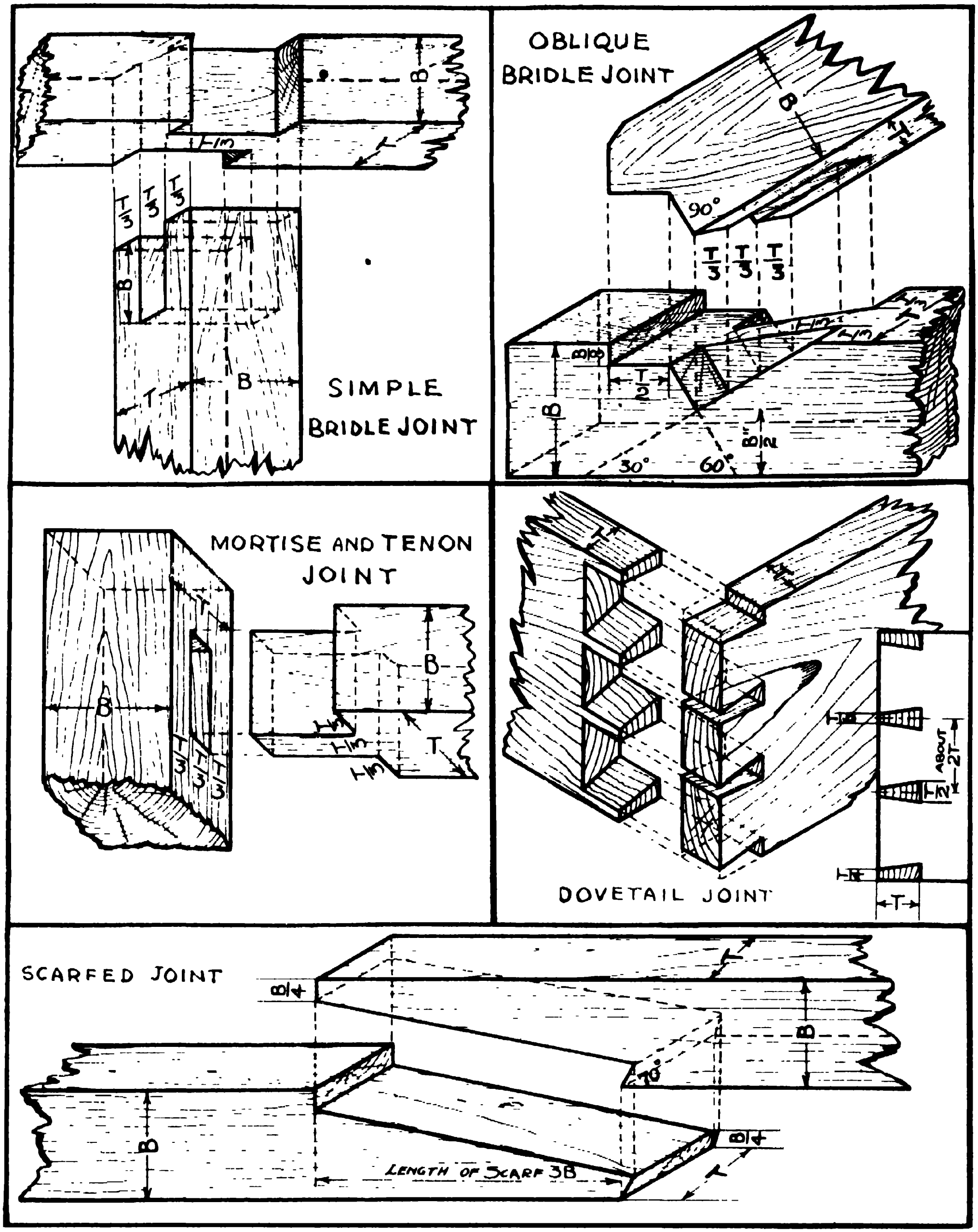
The Simple Bridle Joint. This joint may be used in nearly all cases where a halving or mortise and tenon joint is used. It is an expensive joint to make but has the advantage of having every part of the joint visible while being fitted and put together.

The Oblique Bridle Joint. This shows the application of the oblique bridle joint at the junction of the rafter and tie beam in a roof truss.

The Mortise and Tenon Joint. This joint, in one or other of its variations, is that most frequently used by the woodworker. It is easily constructed, is strong, and gives a neat finished appearance. A solid rectangular tongue or projection (called the tenon) is formed on one member and a slot (called the mortise) is cut in the other to receive the tenon. The joint is usually fastened together with glue, small wedges or wooden dowel pins. The tenon, which is formed in the direction of the grain, is usually about one-third the width of the material.

The Common Dovetail Joint. This joint is used for connecting two thin pieces of wood together, *e.g.*, at the sides of boxes, drawers, cabinets, etc. Projecting pins are formed on one member and these enter recessed dovetails in the other. It is a very strong and neat joint.

The Scarfed Joint. This joint is used when timbers have to be joined in the direction of their lengths at the same time retaining their cross section. The joint is generally held together by bolts and nuts passing through both members.


SIMPLE BRIDLE JOINT
OBLIQUE BRIDLE JOINT
90°
30°
60°
MORTISE AND TENON JOINT
DOVETAIL JOINT
ABOUT 2T
SCARFED JOINT
LENGTH OF SCARF 3B

ROOFS. PLATE 28

Roofs provide the necessary covering over the inside of a building as a protection against weather conditions. They serve to brace or tie the walls together rigidly to the whole building. Roofs are "*pitched*", to a lesser or greater extent, according to the materials covering them. This *pitch* is expressed either in terms of the span of the building or as an angle with the horizontal. The formation of the roof is modified according to the span. Fig. 121 shows the outline formation for various spans of timber roofs.

Lean-to Roof has one slope only and is used for small spans, e.g., covering outbuildings such as a shed or hot-house standing against the main building.

Couple Roof is composed of two sloping rafters ; one of the ends rests on the wallhead and the others meet at the ridge. There is a tendency to *spread*, or push the walls in an outward direction, as no tie is used. The walls themselves must therefore be stable enough to resist this thrust.

Collar Roof is similar to the couple roof, only a tie is provided half-way up the rafters to bind them together. This tie also provides a fixing for the ceiling of the room below and gives headroom. The finished appearance at the tops of the walls in that room will converge, when the room is said to have a "*combe*" ceiling.

Couple Close Roof is that where the rafter tie is lowered to the foot of the rafters and becomes a roof joist.

King Post Roof. It is now necessary to insert struts to support the rafters themselves as these have become too long for the weight they have to carry. The centre post affords a convenient means of joining the struts to the roof joist.

Hipped Roof. The walls are carried to the same level all round the building and the ends of the roof are pitched as well as the sides.

Gabled Roof. The end walls of the building are carried up into the triangular space formed by the meeting of the two end rafters.

EXERCISE 23. PLATE 28

1. Draw, to a scale of $\frac{1}{8}''$ to a foot, the line diagrams for roofs of various spans; also the three views of the hipped and gabled roofs (Fig. 121).
2. Draw, to a scale of $\frac{1}{2}''$ to a foot, the details of the couple roof and make an enlarged detail at the wall head to a scale of $\frac{1}{8}$th full size (Fig. 122).
3. Draw, to a scale of $\frac{1}{2}''$ to a foot, the detail of the collar roof and make an enlarged detail at the wall head to a scale of $\frac{1}{8}$th full size (Fig. 123).

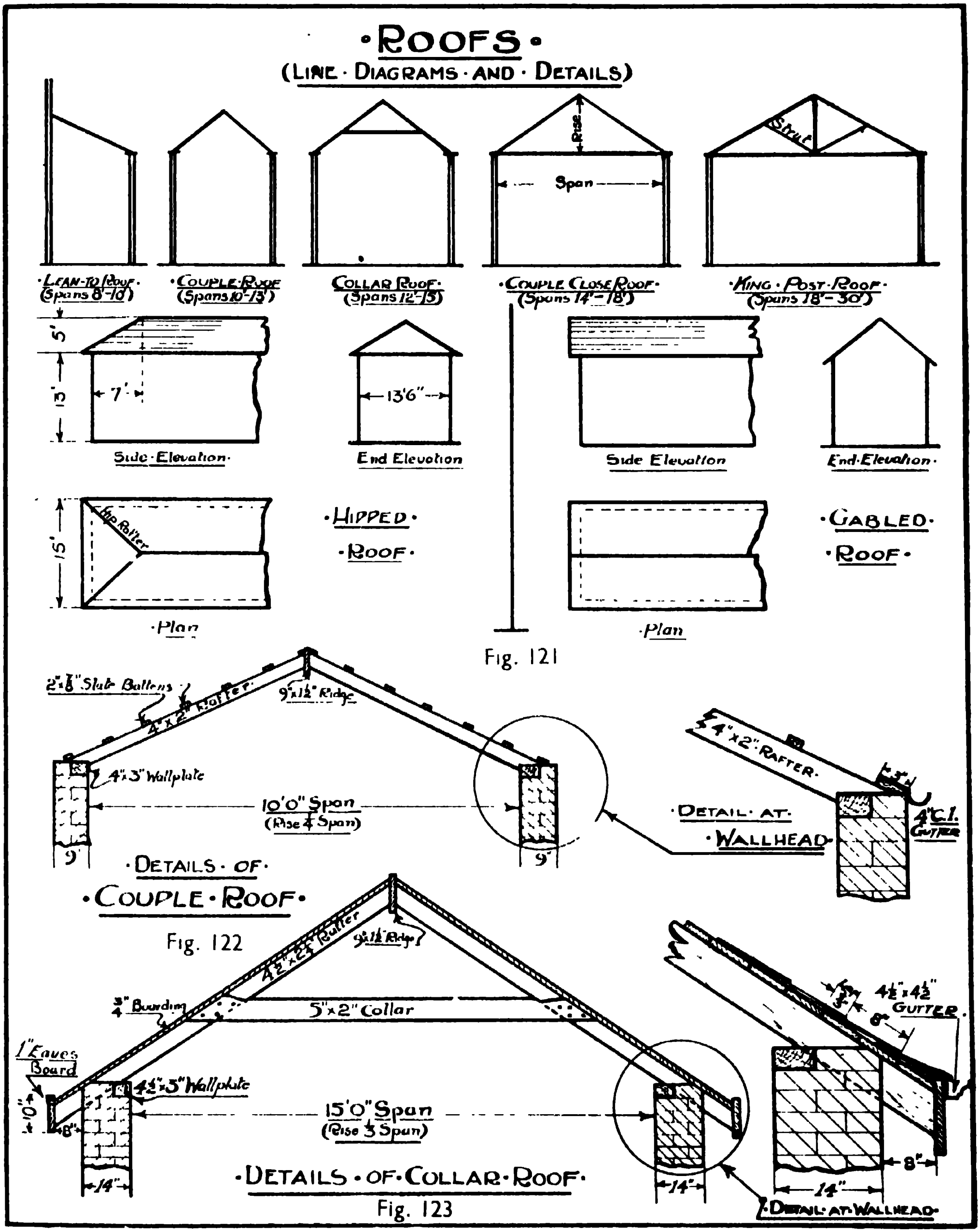


Fig. 121

Fig. 122

Fig. 123

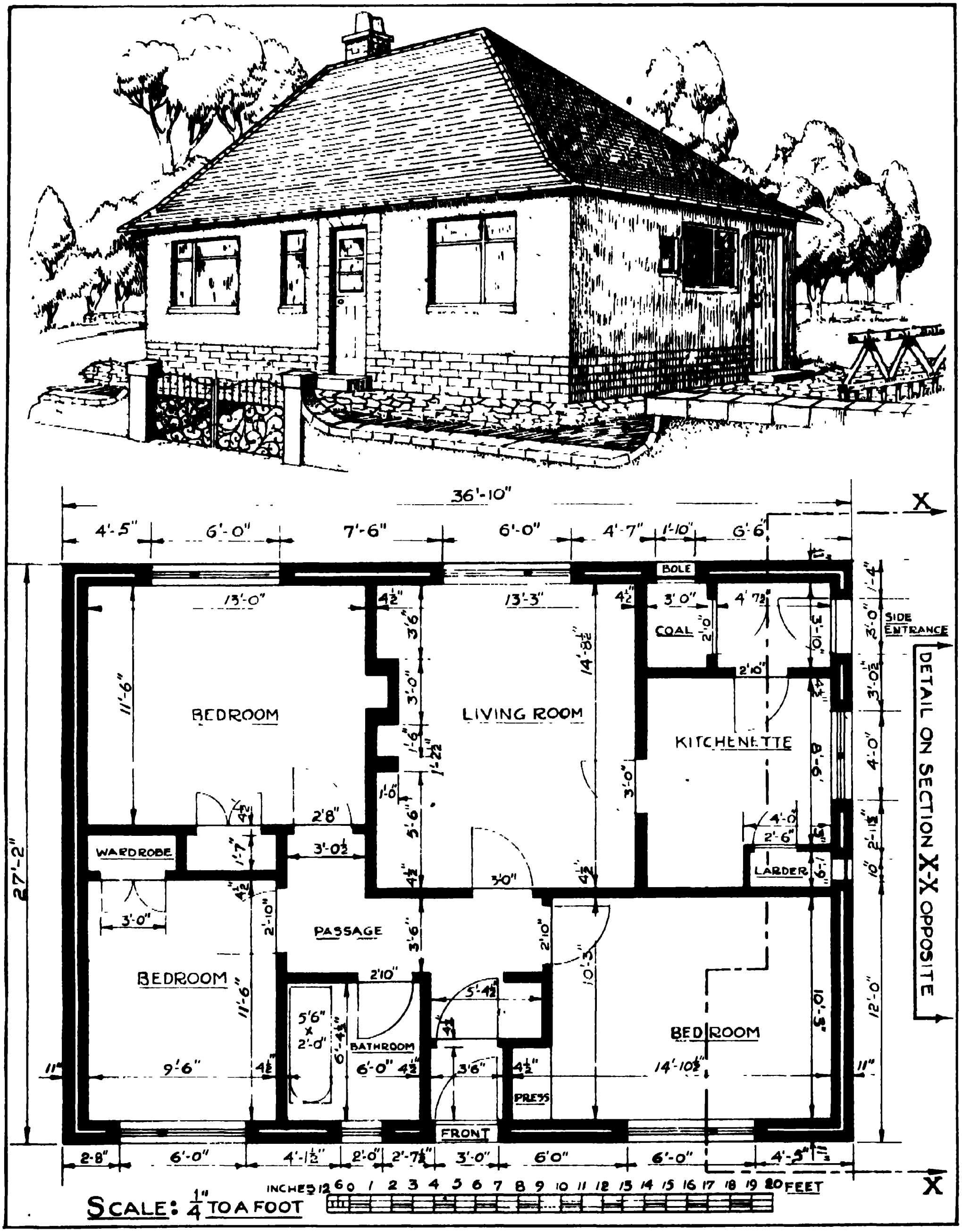

36'-10"
4'-5"
6'-0"
7'-6"
6'-0"
4'-7"
1'-10"
6'-6"
X
BOLE
13'-0"
4½"
13'-3"
4½"
3'0"
4'7½"
COAL
SIDE ENTRANCE
BEDROOM
LIVING ROOM
KITCHENETTE
DETAIL ON SECTION X-X OPPOSITE
11'-6"
14'-8½"
WARDROBE
2'8"
3'-0½"
3'0"
LARDER
2'10"
3'-0"
PASSAGE
BEDROOM
BEDROOM
5'6" x 2'-0"
BATHROOM
2'10"
5'-4½"
9'-6"
6'-0"
3'6"
14'-10½"
PRESS
FRONT
27'-2"
12'-0"
11"
2-8"
6'-0"
4'-1½"
2'-0"
2'-7½"
3'-0"
6'0"
6'-0"
4'-5"
INCHES 12 6 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 FEET
SCALE: ¼" TO A FOOT

PLATE 29

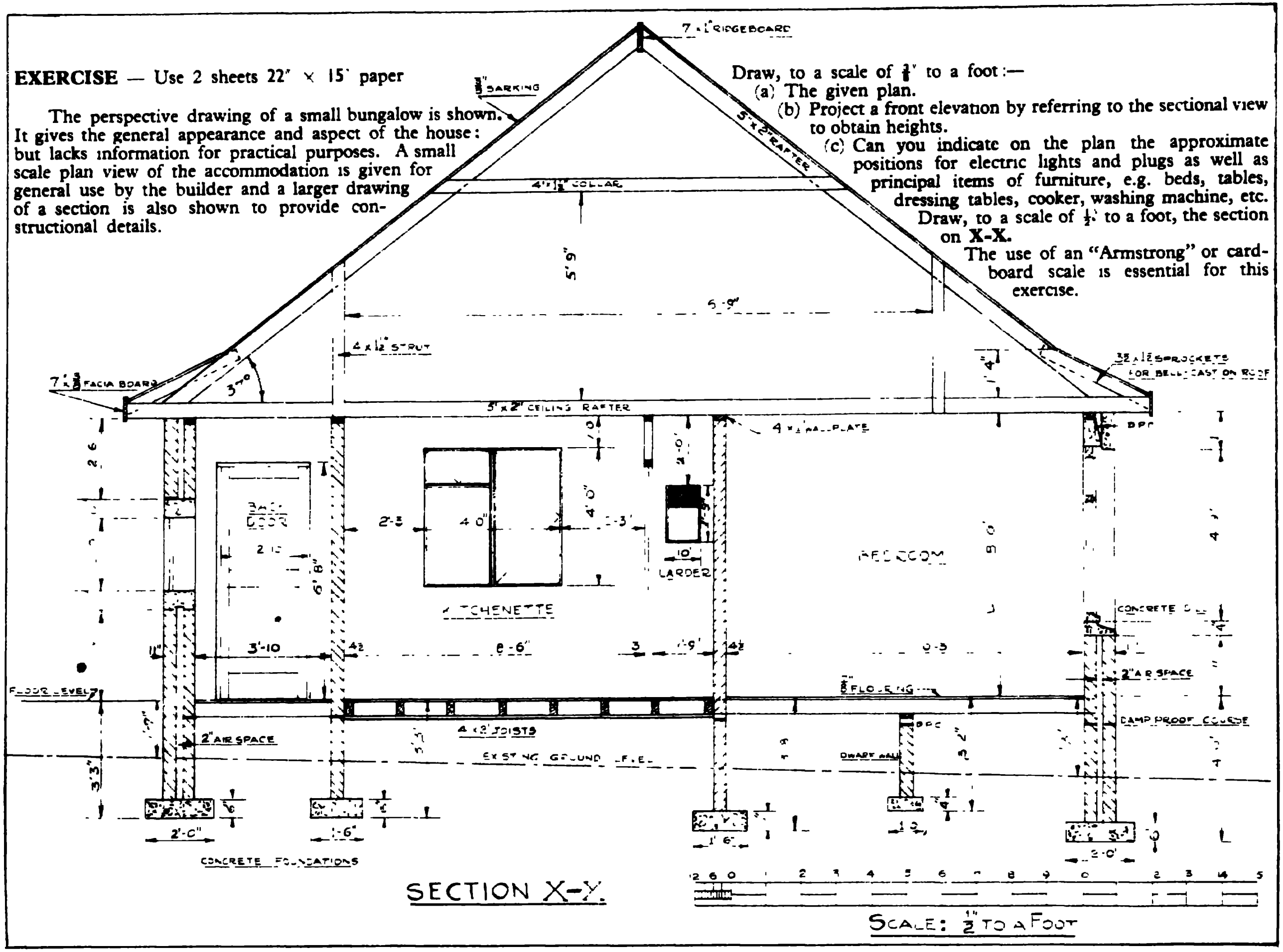
EXERCISE — Use 2 sheets 22″ × 15″ paper

The perspective drawing of a small bungalow is shown. It gives the general appearance and aspect of the house: but lacks information for practical purposes. A small scale plan view of the accommodation is given for general use by the builder and a larger drawing of a section is also shown to provide constructional details.

Draw, to a scale of $\frac{1}{4}$″ to a foot:—
(a) The given plan.
(b) Project a front elevation by referring to the sectional view to obtain heights.
(c) Can you indicate on the plan the approximate positions for electric lights and plugs as well as principal items of furniture, e.g. beds, tables, dressing tables, cooker, washing machine, etc.

Draw, to a scale of $\frac{1}{2}$″ to a foot, the section on **X-X.**

The use of an "Armstrong" or cardboard scale is essential for this exercise.



THE CAVITY OR HOLLOW WALL. PLATE 30

The outside walls of houses and small buildings are usually built in two portions and separated vertically by a space, or cavity, of from 2″ to 3″. This space prevents any moisture from seeking its way from the outer to the inner walls of the house and also prevents the house from being subjected to severe changes in temperature.

Tilting Fillet is a triangular shaped piece of wood fixed to the roof boarding where the latter comes down on the wall head. The purpose of the fillet is to give a lift, or tilt, to the slates at this junction so that water will not lodge about the wallhead.

Branders are straps of wood nailed to the underside of the ceiling ties. Thin strips of wood called *laths* are fixed to these branders, a space of about ½″ being left between the laths. The ceiling is then plastered, when the plaster seeks its way between and behind the laths to form a *key* for the suspension of the plaster.

Wallplate is fixed to the wallhead and provides a fixing for the rafters.

Lintels shown are made of concrete and are cast previously. They contain steel rod re-inforcements to make them stronger.

Window Case is the fixed wooden framework of the window ; it provides a fixing for the hanging of the window sashes.

Outside, Parting, and Inside Beads act as "*guides*" forming a constrained path in which the window sashes run.

Metal Tongue runs the length of the window sill. Its purpose is to prevent moisture finding its way between the stone or concrete sill and the window case sill.

Weathering is the inclination or "*run*" on the top outside face of the sill to run the rainwater away from the window case sill.

Throating is the groove along the underside of the sill so that the rainwater coming from the weathered sill will drip away from the face of the wall.

Breeze Concrete is a mixture of ashes and cement previously cast to the required dimensions. Partitions inside a house are often made up of thin breeze blocks about 2″ thick.

Asphalt and Damp-proof Felt Courses are inserted as a precaution wherever there may be a possibility of moisture penetrating, or being drawn up from the ground, into the inside of the house.

Cement Harling is a rendering of cement and sand to the outside face of the bricks. Pebbles, or small whin chips, are bedded in this rendering to give a finish to the wall.

Galvanised Louvre Ventilator is a metal covering formed of *louvred* pieces of thin iron galvanised to prevent rusting. Its purpose is to allow air to circulate about the flooring joists to prevent deterioration known as "*dry rot*."

Concrete Fundation is required to give a "*spread*" to the superimposed weight of the walls ; it also acts as a suitable bedding for the brick underbuilding.

EXERCISE 25 — Use 22″ × 15″ paper — PLATE 30

Construct a scale of 1″ to a foot and copy this plate, inserting all dimensions and technical information.

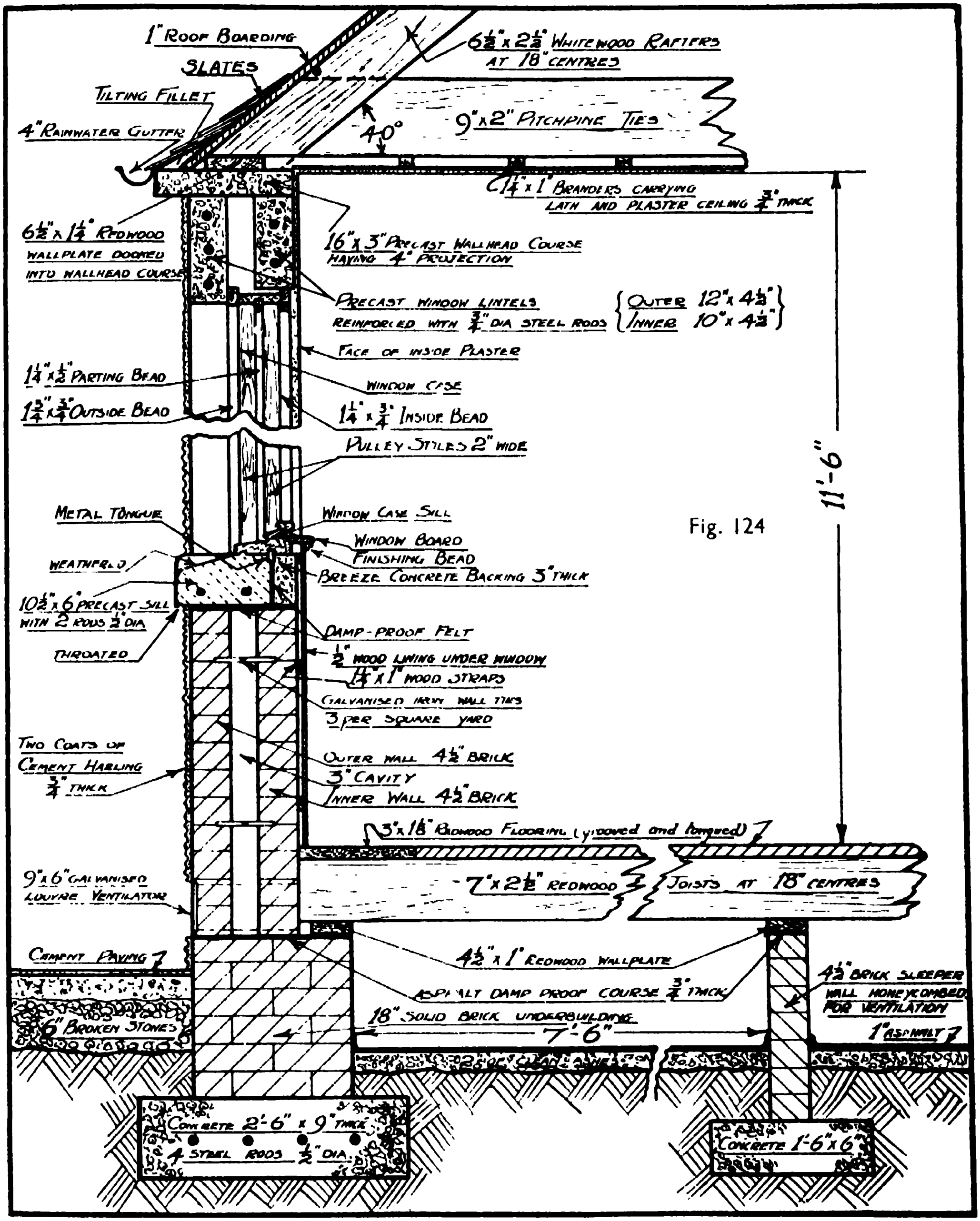

1" Roof Boarding
Slates
Tilting Fillet
4" Rainwater Gutter
6½" x 2½" Whitewood Rafters at 18" centres
9" x 2" Pitchpine Ties
40°
1¼" x 1" Branders carrying lath and plaster ceiling ¾" thick
6½" x 1¼" Redwood wallplate dooked into wallhead course
16" x 3" Precast Wallhead Course having 4" projection
Precast window lintels reinforced with ⅜" dia steel rods
Outer 12" x 4½"
Inner 10" x 4½"
Face of inside plaster
1¼" x ½" Parting Bead
Window case
1¾" x ¾" Outside Bead
1¼" x ¾" Inside Bead
Pulley Stiles 2" wide
Metal Tongue
Window case sill
Window board
Finishing bead
Weathered
Breeze Concrete Backing 3" thick
10½" x 6" precast sill with 2 rods ½" dia
Throated
Damp-proof felt
½" wood lining under window
1¼ x 1" wood straps
Galvanised iron wall ties
3 per square yard
Two coats of Cement Harling ¾" thick
Outer wall 4½" brick
3" Cavity
Inner Wall 4½" Brick
11'-6"
3" x 1⅛" Redwood Flooring (grooved and tongued)
7" x 2½" Redwood Joists at 18" centres
9" x 6" Galvanised Louvre Ventilator
Cement Paving
4½" x 1" Redwood Wallplate
Asphalt damp proof course ¾" thick
4½" brick sleeper wall honeycombed for ventilation
18" solid brick underbuilding
7'-6"
1" asphalt
6" Broken Stones
4'
Concrete 2'-6" x 9" thick
4 steel rods ½" dia
Concrete 1'-6" x 6"

Fig. 124

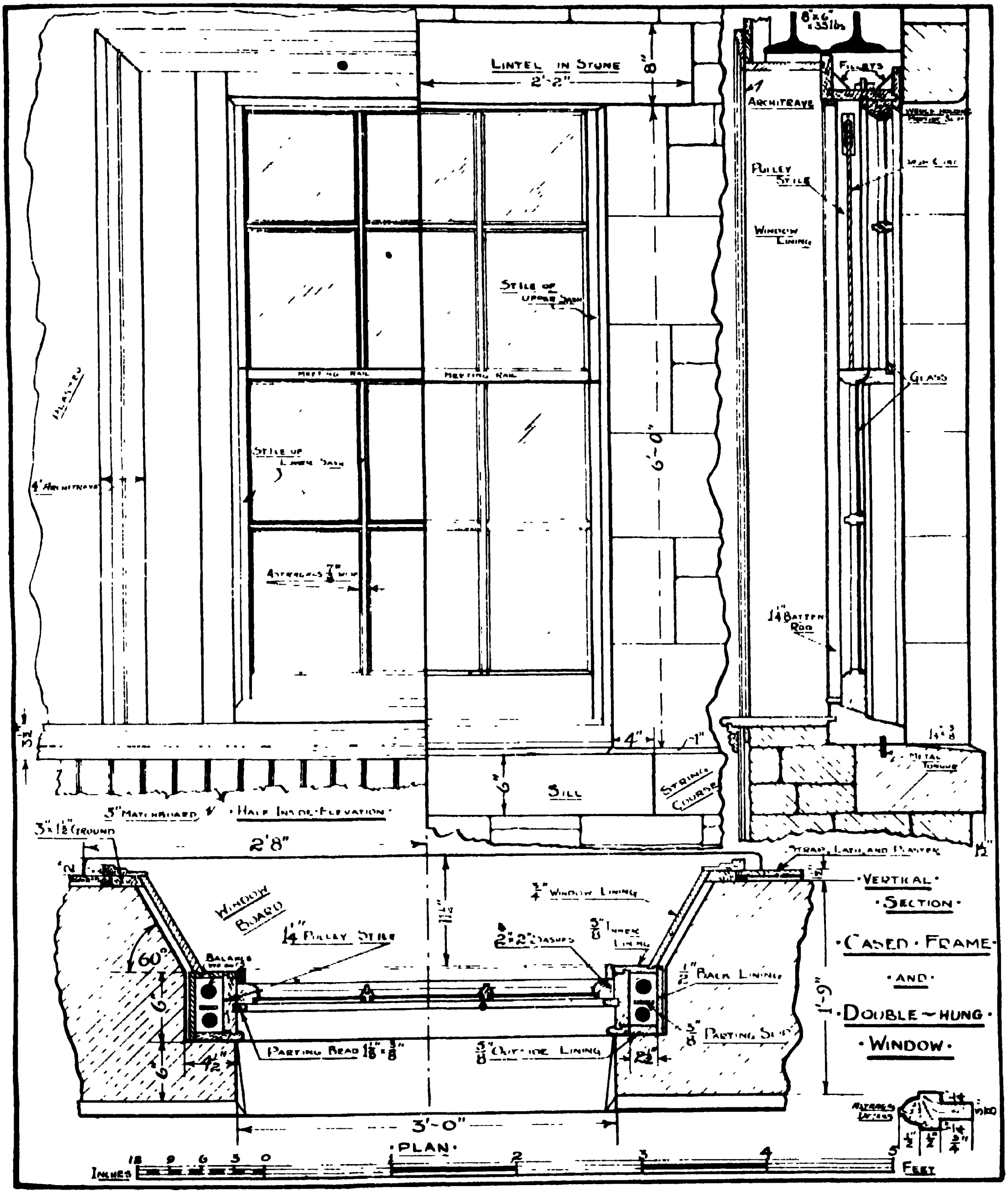
WINDOW HAVING CASED FRAME AND DOUBLE-HUNG SASHES

Plate 31 shows the elevation, sectional plan, and vertical section of the above type of window. The various parts, with dimensions, are shown on the drawings. The window consists of a lower sash and an upper sash, each having two cast-iron balance weights attached. The weights, which are each a little heavier than half the weight of their complete glazed sash, are hung from the sash by a sash cord, or flexible chain, passing freely over a pulley fixed into the pulley stile of the window frame. They act as counter-weights so that only a small effort is required to open the window. They also allow the sashes to remain in any position. If one sash is fixed in the frame and the other sash is movable, the window is said to be *single-hung*. The window is cased to form a long hollow box, within which the weights travel, being prevented from fouling one another as they pass by the *parting slip*. Access to the weights for the purpose of renewing the sash cord, is obtained by providing a rectangular opening in the lower end of the pulley stile. This opening is closed by a *pocket-piece* held in position by being checked into the inner groove of the pulley stile and recessed behind the *parting bead*.

EXERCISE 26 — Use half 22″ × 15″ paper — PLATE 31

Draw, to a scale of $1\frac{1}{2}''$ to a foot, the three views of the cased window frame with double-hung sashes.

PLATE 31


LINTEL IN STONE
2'-2"
8"
ARCHITRAVE
FILLETS
PULLEY STILE
WINDOW LINING
STILE OF UPPER SASH
MEETING RAIL
MEETING RAIL
GLASS
STILE OF LOWER SASH
4" ARCHITRAVE
PLASTER
6'-0"
1¼" BATTEN ROD
METAL TONGUE
4"
1"
6"
SILL
STRING COURSE
3" MATCHBOARD
· HALF INSIDE · ELEVATION ·
3"x1½" GROUND
2'8"
WINDOW BOARD
1¼" PULLEY STILE
¾" WINDOW LINING
2"x2" DASHES
⅝" INNER LINING
½" BACK LINING
60°
PARTING BEAD 1⅛"x⅜"
⅝" OUTSIDE LINING
⅜" PARTING SLIP
4½"
2¼"
3'-0"
1'-9"
· VERTICAL · SECTION ·
· CASED · FRAME · AND · DOUBLE-HUNG · WINDOW ·
· PLAN ·
INCHES 12 9 6 3 0
1 2 3 4 5 FEET

CHAPTER 4

FURTHER TANGENCY — SPECIAL CURVES (SINE [SIMPLE HARMONIC] CURVE — ELLIPSE — PARABOLA — HYPERBOLA — CYCLOID — EPICYCLOID — HYPOCYCLOID — INVOLUTE)— SPIRALS (ARCHIMEDEAN — LOGARITHMIC — SCROLL) — HELIX (CIRCULAR AND CONICAL) — COIL SPRING — IRREGULAR OR "FRENCH" CURVES

REVERSED (CIRCULAR) CURVES

To join two parallel lines with a reversed (quadrant) curve, when the sum of the given radii is EQUAL TO the distance the lines are apart.

Fig. 125. Let **AC** and **FG** be the lines to be joined with a reversed (quadrant) curve of different radii (**R_1** and **R_2**) and the curve to commence at the point **B** on **AC**.

Draw **XY** parallel to **AC** at a distance **R_1** from it (**XY** will be **R_2** from **FG**).

Drop a perpendicular from **B** to **XY**, giving centre **O^1**.

With centre **O^1** and radius **R_1** draw the curve **BE**.

Make **EO^2** **R_2**. With centre **O^2** and radius **R_2** draw the curve **ED**.

BED is the required curve.

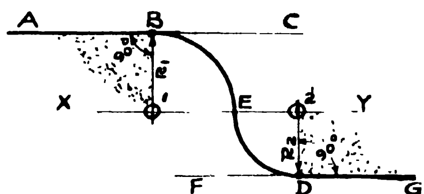


Fig. 125

To join two parallel lines with a reversed curve, when the sum of the given radii is LESS THAN the distance the lines are apart: the curves to terminate at fixed points on the given lines.

Fig. 126. Let **AB** and **CD** be the lines to be joined with a reversed curve radii ($\mathbf{R_1}$ and $\mathbf{R_2}$) between the fixed points **B** and **C**.

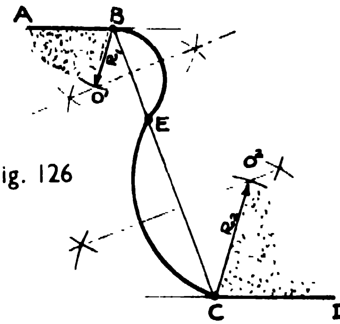


Fig. 126

Join **BC**.

Divide **BC** in the ratio $\dfrac{\mathbf{R_1}}{\mathbf{R_2}}\ \dfrac{\mathbf{BE}}{\mathbf{EC}}$.

Draw the perpendicular bisectors of **BE** and **EC**.

With centres **B** and **C**, and radii $\mathbf{R_1}$ and $\mathbf{R_2}$ respectively, cut these bisectors in $\mathbf{O^1}$ and $\mathbf{O^2}$.

$\mathbf{O^1}$ and $\mathbf{O^2}$ are the centres of the required curve **BEC**.

Fig. 127 illustrates the case when the sum of the given radii is **GREATER THAN** the distance the lines are apart.

The construction is exactly similar to that for Fig. 126 and can be followed on Fig. 127.

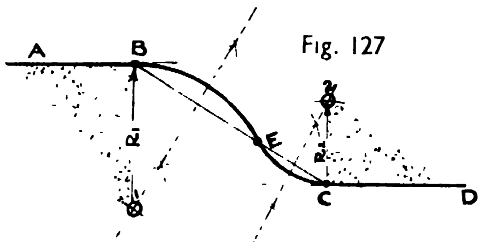


Fig. 127

To determine the radii of a reversed curve, joining two parallel lines, the curve to be TANGENTIAL at given points on the lines and to reverse at a fixed position on the line joining the given points.

Fig. 128. Let **AB** and **CD** be the lines, **B** and **C** the given points and **E** (on **BC**) the point of reversal of the curve.

Draw the perpendicular bisectors of **BE** and **EC**.

At **B** and **C** draw perpendiculars to **BA** and **CD** meeting the bisectors in $\mathbf{O^1}$ and $\mathbf{O^2}$.

$\mathbf{O^1B}$ and $\mathbf{O^2C}$ are the required radii ($\mathbf{R_1}$ and $\mathbf{R_2}$).

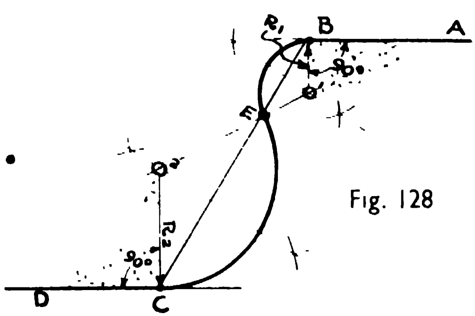


Fig. 128

To draw the arc of a circle tangential to a straight line and to an arc of a given circle.

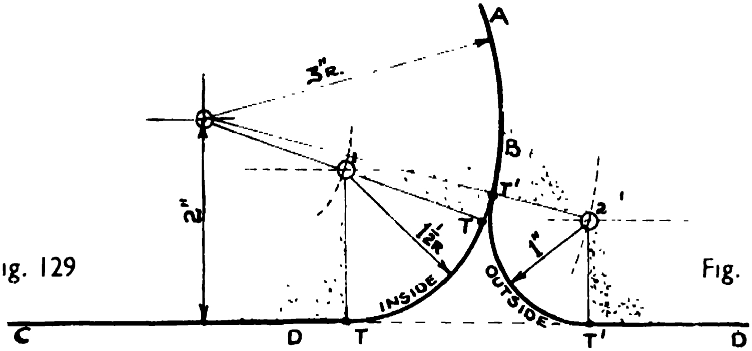


Fig. 129

Fig. 130

Fig. 129. Let **CD** be the straight line and **AB** the given arc (3″ rad.) to be joined by a curve of $1\frac{1}{2}''$ radius.

Draw a line (broken) parallel to **CD** and $1\frac{1}{2}''$ from it.

With centre **O** and $1\frac{1}{2}''$ radius (i.e., $1\frac{1}{2}''$ **less than** the radius of the given arc **AB**) draw an arc (broken) cutting the parallel line in $\mathbf{O^1}$.

Draw a perpendicular from $\mathbf{O^1}$ to meet **CD** in the point **T**. Join $\mathbf{OO^1}$ and produce it to meet the arc **AB** in **T**.

With centre $\mathbf{O^1}$ and $1\frac{1}{2}''$ radius draw the required arc between the points of tangency **T-T**.

Note : The arc **T-T** is part of a circle, " **inside** " the given arc **AB**.

Fig. 130 shows the construction when the required arc $\mathbf{T^1}$-$\mathbf{T^1}$ (1″ radius) is " **outside** " the given arc **AB**.

The construction is similar to that for Fig. 129 except that the arc (broken line) through $\mathbf{O^2}$ has a radius of 4″ from **O** (i.e., 1″ **more than** that of the given arc **AB**) and the point of tangency is where the line joining $\mathbf{OO^2}$ cuts the arc **AB** in $\mathbf{T^1}$.

To draw the arc of a circle tangential to two given arcs.

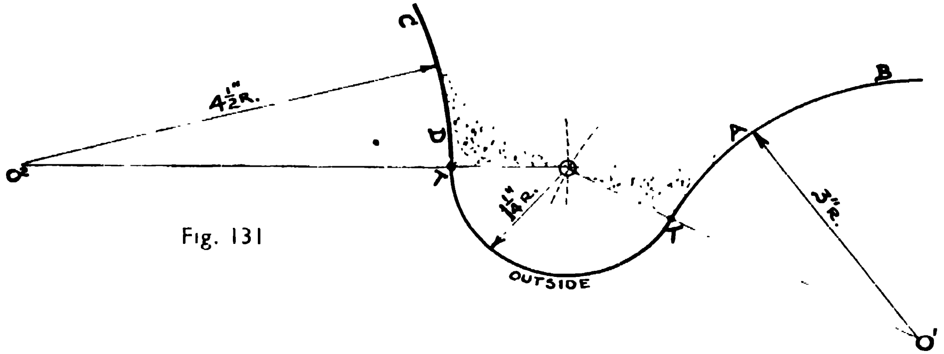


Fig. 131

Fig 131 shows the construction required when the required arc is **outside** the given arcs.

With centre **O**¹ and $4\frac{1}{4}''$ radius ($3'' + 1\frac{1}{4}''$) describe an arc (broken line) and with centre **O**² and $5\frac{3}{4}''$ radius ($4\frac{1}{2}'' + 1\frac{1}{4}''$) draw a similar arc intersecting the previous one in **O**.

Join **OO**¹ and **OO**² to obtain the points of tangency **T** on the arcs **AB** and **CD**.

With centre **O** and radius **OT** ($1\frac{1}{4}''$) draw the required arc between **T-T**.

Fig. 132 shows the construction when the required arc is **inside** the given arcs and is similar to that for Fig. 131 except that radius **O**¹**O** is $\frac{3}{4}''$ ($1\frac{3}{4}'' - 1''$) and the radius **O**²**O** is 3" (4" - 1"). Produce **O**¹**O** and **O**²**O** to meet the given arcs in the points **T.T.**

With centre **O** and radius **OT** (1") draw the required arc between **T-T.**

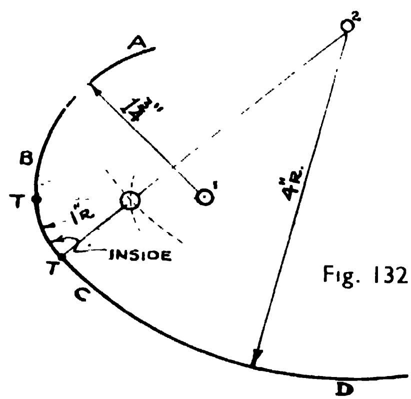


Fig. 132

EXERCISE 27 — Use half 22″ × 15″ paper

Fig. 133 shows the section of a casting. Copy this to the particulars given and mark, with a heavy dot, all the points of tangency. Insert all dimensions.

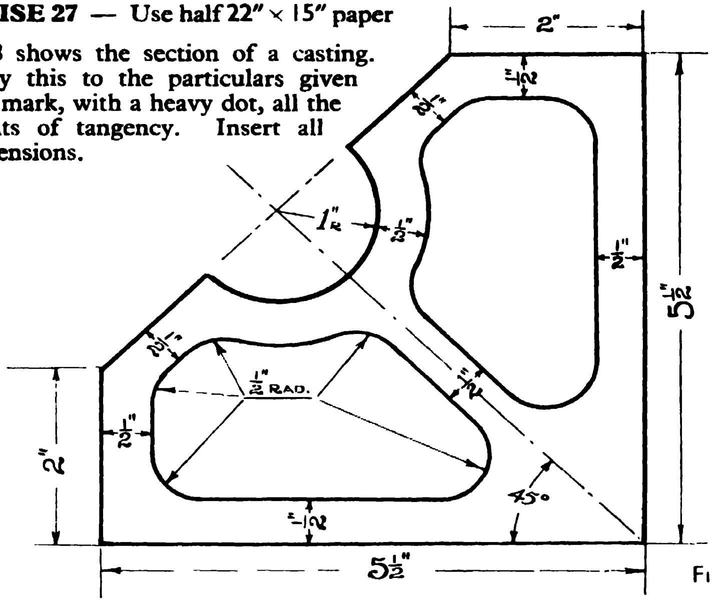


Fig. 133

Fig. 134 shows the outline of a spacer. Copy this to the particulars given and mark, with a heavy dot, all the points of tangency. Insert all dimensions.

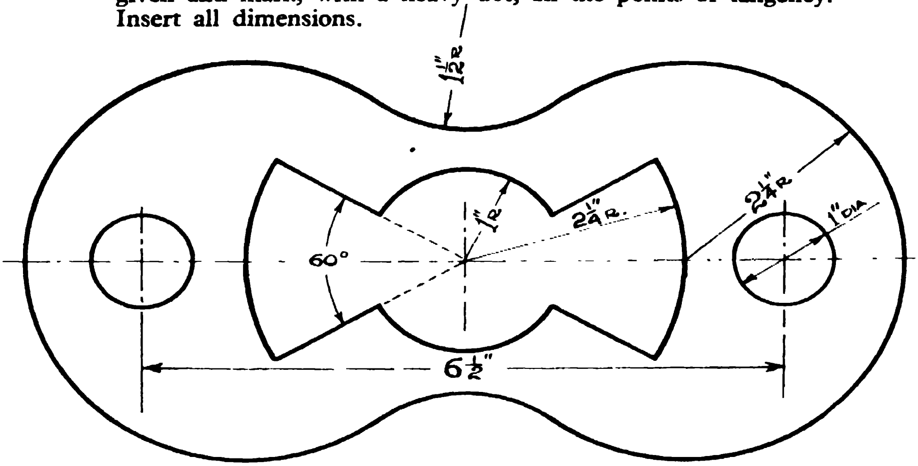


Fig. 134

EXERCISE 28 — Use half 22″ × 15″ paper

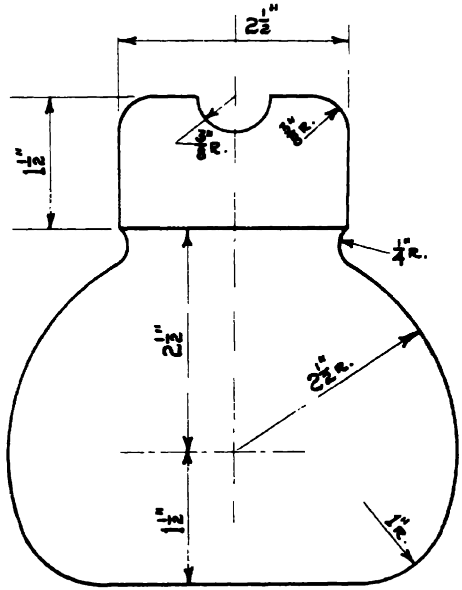


Fig. 135

Fig. 135. Draw the outline of the porcelain insulator and mark, with a heavy dot, all points of tangency.

Fig. 136. Draw the chemical flask with cork and glass tubing and mark, with a heavy dot, all points of tangency.

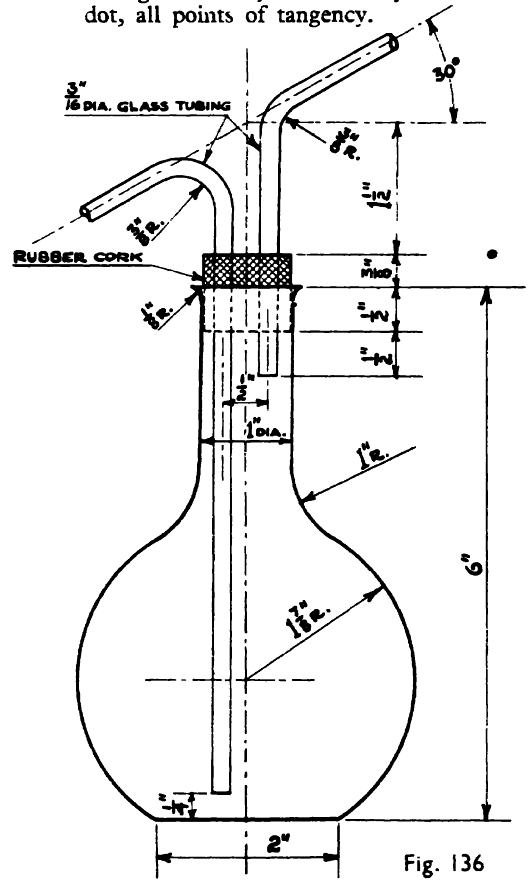


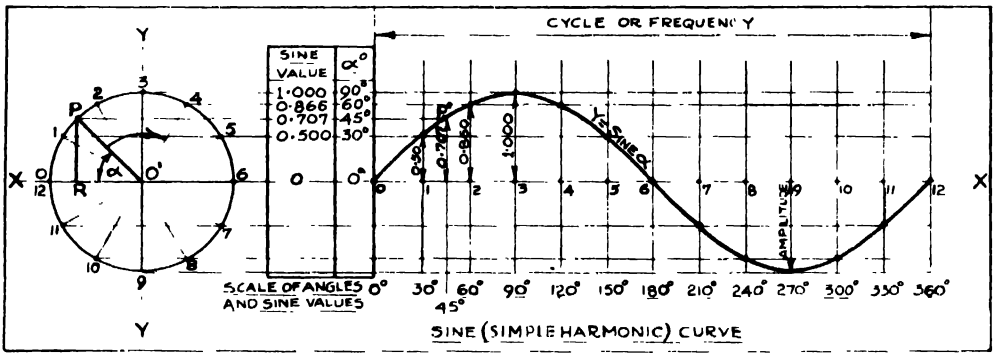
Fig. 136

SPECIAL CURVES

SINE (Simple Harmonic) CURVE

CONIC SECTIONS	CYCLOIDAL CURVES	SPIRALS
Ellipse	**Cycloid**	**Archimedean**
Parabola	**Epicycloid**	**Logarithmic**
Hyperbola	**Hypocycloid**	**Scroll**
	Involute	

HELIX — COIL SPRING — IRREGULAR OR " FRENCH " CURVE



Sine (Simple Harmonic Curve). The sine of an angle (α) is the ratio $\dfrac{\mathbf{PR}}{\mathbf{O'P}}$ and increases, at a varying rate, from 0° to **1** at 90° and thereafter decreases to 0° at 180°. The same pattern is repeated between 180° and 360°.

Draw a circle having a radius of one unit (say 1") and divide its circumference into 12 equal parts.

Set off on **XX** any length to represent 360° (cycle or frequency) and divide it into 12 equal parts (**0, 1, 2, - - 11, 12**). The distance between the points represents 30°. Draw vertical lines through the points.

From the similarly marked points on the circle draw horizontal lines parallel to **XX** to intersect the correspondingly numbered vertical lines to give points on the curve.

Draw a smooth curve through these points of intersection to obtain the curve $Y = \text{Sine}\ \alpha$.

$$\text{Sine}\ \alpha = \frac{\mathbf{PR}}{\mathbf{O'P}} = \frac{\mathbf{PR}}{\mathbf{radius}} = \mathbf{PR}\ \text{when radius is}\ \mathbf{unity.}$$

Thus the projection of a point **P** on the vertical diameter (3.9) is a measure of **sine** α.

If α is 45° then the horizontal line from **P** meets the curve in **P′** and the ordinate at this point is the value of sine 45° (0.707).

The sine curve is used in the solution of problems in engineering and physics.

EXERCISE. Super-impose the cosine curve for the ratio cos. $\alpha = \dfrac{\mathbf{O'R}}{\mathbf{O'P}} = \mathbf{1}$ when $\alpha = 0°$. This curve will lag 90° behind the sine curve.

THE ELLIPSE

SOME DEFINITIONS AND PROPERTIES

The Ellipse, Fig. 137, is a plane figure bounded by a curved line whose path is traced out by a point which moves so that the sum of its distances from two fixed points, F^1 and F^2, called the foci (plural of "focus"), is constant, e.g., $CF^1 + CF^2 = HF^1 + HF^2 = AB$ (major axis of the ellipse).

Diameter : Any straight line which passes through the centre of an ellipse, and is terminated, both ways by the curve, is called a diameter (**EG**).

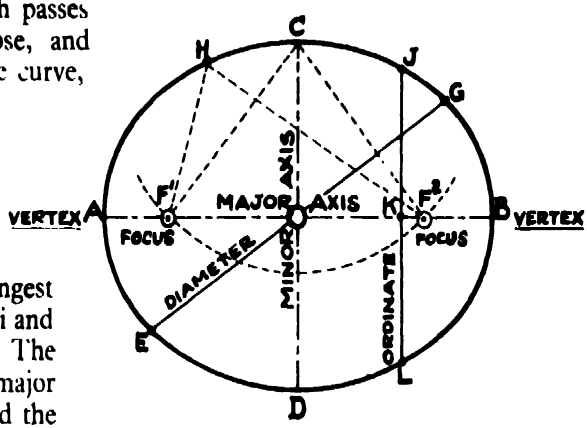


Fig. 137

Major and Minor Axes : The longest diameter passes through the foci and is called the major axis (**AB**). The shortest diameter bisects the major axis at right angles and is called the minor axis (**CD**). The ellipse is symmetrical about its major and minor axes.

Foci : These points are obtained by taking **C** (one end of the minor axis) as centre and radius **AO** (semi-major axis) and cutting the major axis in F^1 and F^2.

Vertices: The extremities of the major axis, **A** and **B**, are called vertices (plural of "vertex").

Ordinate : Any straight line drawn perpendicular from a point on the major axis and terminating on the curve is an ordinate, e.g., **KJ** and **KL**. **JL** is a double ordinate.

Sometimes an ellipse is referred to as an "*oval,*" e.g., when referring to an elliptical mirror as an oval mirror. This is not strictly correct, as an oval has a flatter curve at one end than the other, similar to the shape of an egg.

To draw an ellipse when the major and minor axes (or diameters) are given : Fig. 138.

Draw the circumscribing rectangle, i.e., the rectangle whose length and breadth are the same lengths as the major and minor axes of the ellipse, respectively.

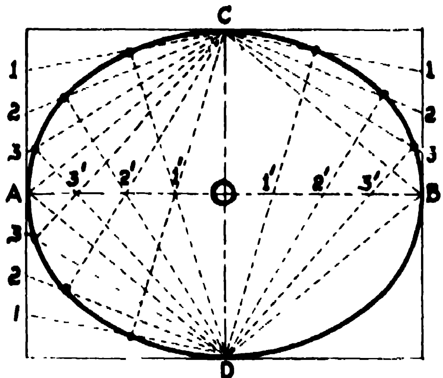


Fig. 138

Divide the upper side of the rectangle, which represents half the minor axis of the ellipse, into any number of equal parts, say 4, as shown 1, 2, 3, A.

Similarly divide the adjacent half of the major axis (**AO**) into the same number of equal parts as shown **0**, $\mathbf{1^1}$, $\mathbf{2^1}$, $\mathbf{3^1}$.

Join **C1, C2, C3, CA.**

Draw $\mathbf{D1^1}$ and produce it to meet **C1** giving a point on the ellipse.

The other points for this quadrant are obtained in the same way.

Draw a "*smooth*" uniform curve through the points so obtained terminating in **A** and **C.**

Repeat for the second quadrant as shown in Fig. 138 thus giving the upper half of the ellipse.

The lower half of the ellipse is obtained by reversing the method, using point **D** in the same manner as was done with point **C** (see lower left hand quadrant).

Only one quadrant requires to be drawn ; the others may be obtained from it by the use of tracing paper.

To draw an approximate ellipse using compasses from four centres : Fig. 139.

Let **AB** and **CD** be the given major and minor axes of the ellipse.

Join **AC.**

With centre **C** and radius equal to the difference between half the major and half the minor axes, (**OA - OC**), cut the line **CA** in the point **X**.

Draw the bisector of **AX** meeting **OA** in **O^1** and produce to meet **OD** in **O^4**.

$OO^3 = OO^1$ and **$OO^2 = OO^4$**.

Join **O^2O^1** and **O^2O^3** and produce (broken lines) towards **H** and **G.**

Similarily with **O^4O^1** and **O^4O^3** and produce towards **E** and **F.** With centres **O^1** and **O^3** and radii **O^1A** and **O^3B** respectively draw the arcs **E-H** and **F-G.**

With centres **O^2** and **O^4** and radii **O^2D** and **O^4C** respectively draw the arcs **H-G** and **E-F** to complete the approximate ellipse.

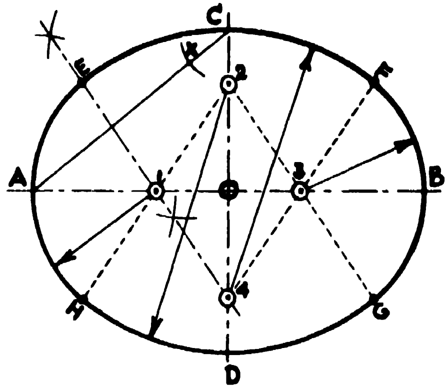
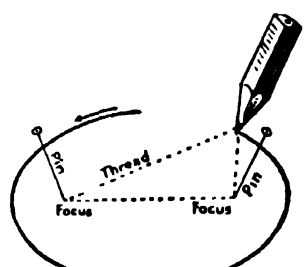


Fig. 139

PRACTICAL METHODS OF DRAWING AN ELLIPSE WHERE THE MAJOR AND MINOR AXIAL LIMITS ARE FIXED

Pin and Thread Method : Fig. 140 : This practical construction depends on the fundamental property of the ellipse, viz., that the sum of the distances from the foci to any point on the curve is constant (Fig. 137). Insert a pin at each focus and a third pin at one extremity of the minor axis. Arrange a loop of thread round the three pins (see **F^1. F^2 C.,** Fig. 137). Remove the third pin and substitute a pencil point. Move the pencil round keeping even tension on the loop of the thread. The curve described will be an ellipse.

Gardeners use this method to lay out elliptical flower plots, poles and twine serving the purpose of the pins and thread.



PIN AND THREAD METHOD.

Fig. 140

Trammel Method : Fig. 141 : On a piece of stiff paper or cardboard, mark off **EF – AO** and **EG – CO.** Place the paper so that **G** is on the major axis and **F** on the minor axis. **E**, will give a point on the curve. Move the paper to various positions so that **G** is always on the major axis and **F** always on the minor axis, when **E** will give a number of points on the curve. Draw a smooth curve through these points.

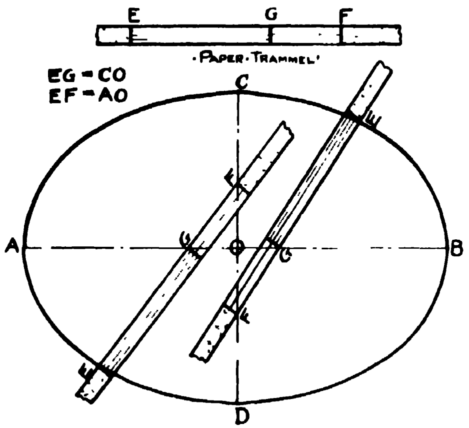


Fig. 141

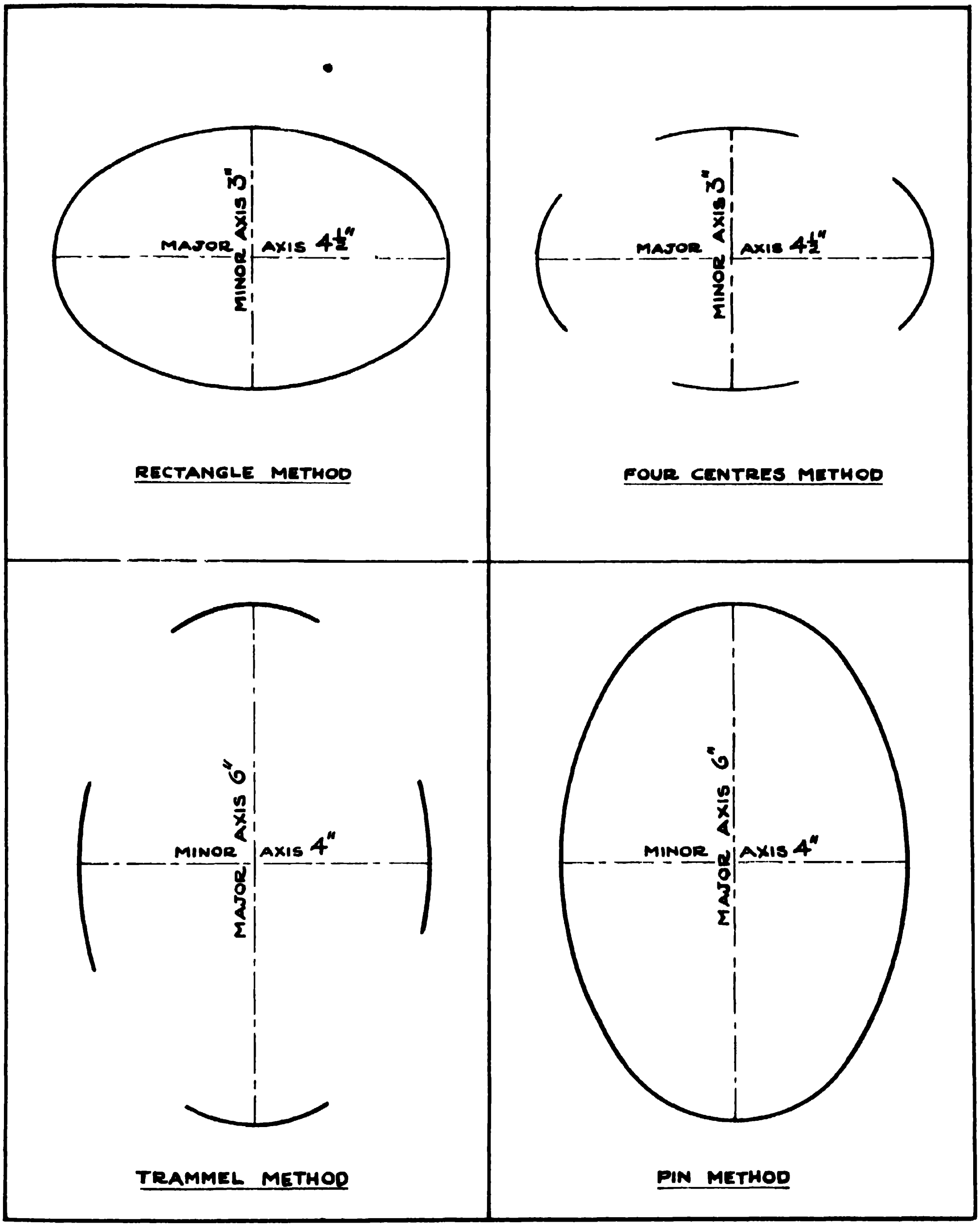
Draughtsmen make use of this method to draw an ellipse rapidly.

An instrument used by joiners and known as the **"Elliptical Trammel "** *is based on this principle.*

EXERCISE 29 — Use half 22″ × 15″ paper — **PLATE 34**

Divide the paper as shown and draw four ellipses to the dimensions given and by the required method in each case. •

PLATE 34


MAJOR AXIS 4½"
MINOR AXIS 3"
RECTANGLE METHOD
MAJOR AXIS 4½"
MINOR AXIS 3"
FOUR CENTRES METHOD
MINOR AXIS 4"
MAJOR AXIS 6"
TRAMMEL METHOD
MINOR AXIS 4"
MAJOR AXIS 6"
PIN METHOD

ELLIPSE PARABOLA — HYPERBOLA

The ellipse, the parabola and the hyperbola cannot be drawn with a pair of ordinary compasses. These curves, however, may be regarded as the locus (or path) of a point which moves in a plane according to a definite law.

THE ELLIPSE

The ellipse as the locus of a point. The ellipse is the curve traced out by a point moving, in the same plane, in such a way that its distance, from a fixed point (called the *focus*) bears a constant ratio, **less than unity,** to its perpendicular distance from a fixed straight line (called the *directrix*). This ratio is called the **eccentricity (e)** of the ellipse. An ellipse has two directrices and two foci.

To draw an ellipse given the directrix, the focus and the eccentricity (Fig. 142).

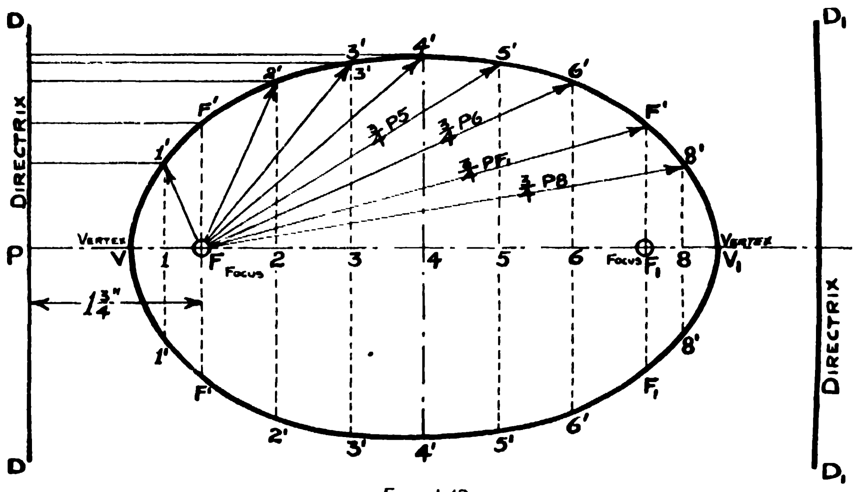


Fig. 142

Eccentricity $= \frac{3}{4}$.

To Obtain the Distance PV.

$FV = \frac{3}{4}PV$; $\therefore (1\frac{3}{4}'' - PV) = \frac{3}{4}PV$;
$\therefore PV = 1''$.

To Obtain the Distance PV_1.

$FV_1 = \frac{3}{4}PV_1$; $\therefore (PV_1 - 1\frac{3}{4}'') = \frac{3}{4}PV_1$;
$\therefore PV_1 = 7''$.

Let **DD** be the directrix, **F** the focus and the eccentricity $\frac{3}{4}$.

Let the distance of the focus from the directrix be $1\frac{3}{4}''$.

Draw **PF** perpendicular to **DD** and produce it.

Obtain **V** and $\mathbf{V_1}$, the vertices of the ellipse, as shown by the calculations in the figure.

Mark off any number of points 1, **F**, 2, . . . $\mathbf{F_1}$, 8, on $\mathbf{VV_1}$ and draw the ordinates through them.

With centre **F** and radius $\frac{3}{4}$**P**1 cut the ordinate through 1 in the points 1′, 1′, giving two points on the ellipse.

Other points are obtained in the same way and may be followed on the figure.

Draw a smooth curve through the points giving the required ellipse with $\mathbf{e}=\frac{3}{4}$

THE PARABOLA

The parabola as the locus of a point. The parabola is the curve traced out by a point moving, in the same plane, in such a way that its distance from a fixed point (called the *focus*) is equal to its perpendicular distance from a fixed straight line (called the *directrix*). Hence in the case of the parabola the **eccentricity is unity.**

To draw a parabola given the directrix and focus (Fig. 143).

Let **DD** be the directrix and let 2″ be the distance from it to the focus (**F**).

Draw **PF** perpendicular to **DD** and produce it. This gives the axis. **VF** = **VP** because **e** = **1**.

Mark off any number of points 1, **F**, . . . 4 on the axis and draw the ordinates through them.

With centre **F** and radius **P**1 cut the ordinate through 1 in the points 1′, 1′, giving two points on the parabola.

Other points are obtained in the same way and may be followed on the figure.

Draw a smooth curve through the points for the required parabola.

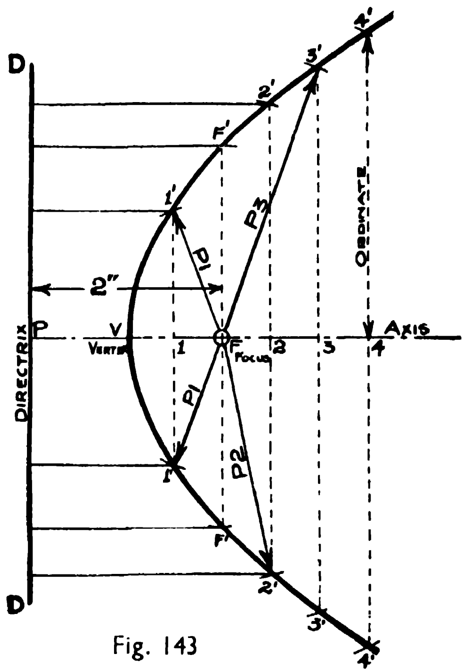


Fig. 143

To draw a parabola given the axis and an ordinate (Fig. 144).

Let 0A (4″) be the axis and **AB** (3″) be the ordinate.

Draw the other ordinate **AC** = **AB**.

The parabola has to pass through the points **B**, 0, **C**.

Complete the rectangle **B44C**.

Divide 04 and 4**B** into the same number of equal parts (4).

Join 1′0, 2′0, 3′0, and through points 1, 2, 3, draw lines parallel to 0**A** intersecting these other lines.

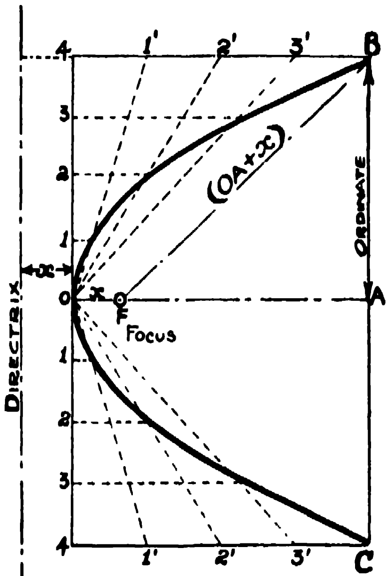


FIG. Fig. 144

To obtain the distance x.

$$FB^2 = FA^2 + AB^2$$
$$(4'' + x)^2 = (4'' - x)^2 + 3^2$$
$$16'' + 8x + x^2 = 16'' - 8x + x^2 + 9''$$
$$16x = 9''$$
$$\therefore x = \tfrac{9}{16}''.$$

A smooth curve through 0, the three points and **B**, will give one-half of the parabola. The other half is obtained in the same way and may be followed on the figure. The calculation for obtaining the focal distance **x** is shown alongside the figure.

THE HYPERBOLA

The hyperbola as the locus of a point. The hyperbola is the curve traced out by a point moving, in the same plane, in such a way that its distance from a fixed point (called the *focus*) bears a constant ratio, **greater than unity,** to its perpendicular distance from a fixed straight line (called the *directrix*). This ratio is called the **eccentricity (e)** of the hyperbola.

To draw a hyperbola given the directrix, the focus and the eccentricity (Fig. 145).

Let **DD** be the directrix, **F** be the focus and the eccentricity be $\frac{3}{2}$.

Let the distance of the focus from the directrix be $1\frac{1}{4}''$.

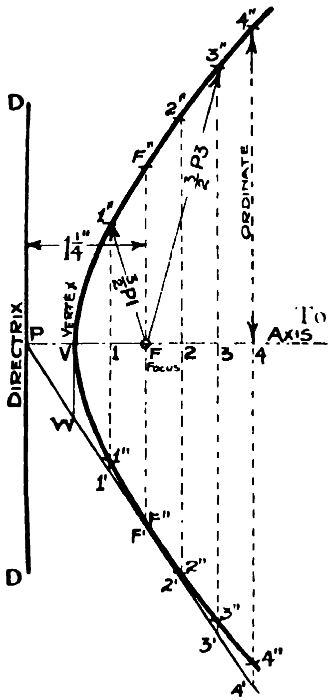
Draw **PF** perpendicular to **DD** and produce it. This gives the axis of the hyperbola.

Obtain **V** as shown by the calculation alongside the figure.

Draw **VW** perpendicular to **PF** and equal to **VF**.

Draw **PW** and produce it.

Mark off any number of points 1, **F**, 2, 3, 4, on the axis and draw the ordinates through them. These ordinates cut **PW** produced in 1′, **F′**, 2′, etc.



To obtain the distance *PV*.

$$FV = \tfrac{3}{2}PV$$

$$(1\tfrac{1}{4}'' - PV) = \tfrac{3}{2}PV$$

$$\therefore PV = \tfrac{1}{2}''.$$

Fig. 145

With centre **F** and radius 1 - 1′ cut the ordinate through 1 in the points 1″, 1″ giving two points on the hyperbola.*

Other points are obtained in the same way and may be followed on the figure.

Draw a smooth curve through the points giving the required hyperbola with **e**

$$* \text{ Since } \mathbf{e} = \frac{VF}{VP} = \frac{VW}{VP} = \frac{1\text{-}1'}{P1} \ldots \text{etc.}$$

CYCLOIDAL CURVES

A cycloidal curve is the path traced out by a point on the circumference of a circle which rolls on a base line, the circle remaining always in the same plane.

Generating Circle : This is the rolling circle.

Generator : This is the point which traces the curve.

Director : This is the fundamental base line, or circle, on which the generating circle rolls.

CYCLOID : Generating circle rolls on a **straight** line.

EPICYCLOID : Generating circle rolls on a **circle** and on the **outside** of it.

HYPOCYCLOID : Generating circle rolls on a **circle** and on the **inside** of it.

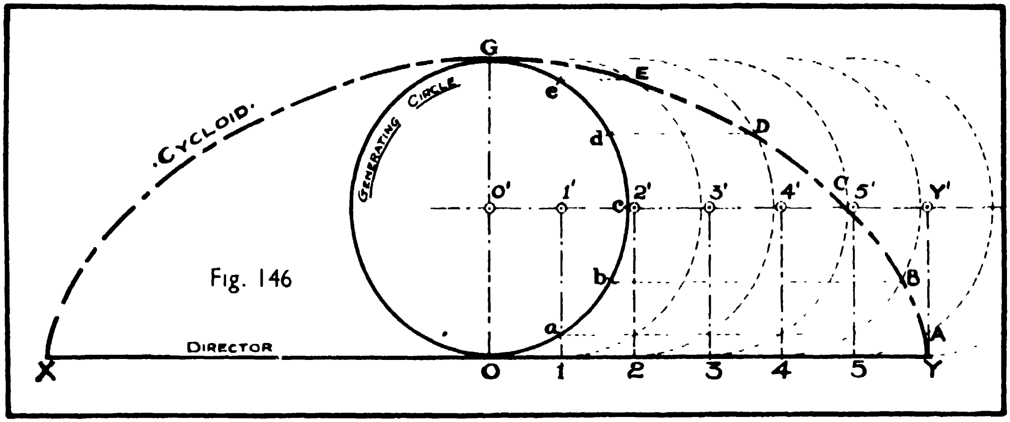


Fig. 146

To draw a cycloid when the generating circle and the director are given, Fig. 146.

Let the generating circle, **GO**, be 3″ diameter and the straight line **XY** be the director.

G is the generator.

Make **OY** equal to one-half the circumference of the generating circle (1.5π ins.).

Divide the semi-circle **OG** into a number of equal parts (say 6) giving the points **a, b, . . . e.**

Divide **OY** into the same number of equal parts (6) giving the points 1, 2, . . . 5.

Draw **O′Y′** parallel to **OY** (This straight line will be the path of the centre **O′** of the generating circle as the latter rolls on the director).

Draw the lines **O0′**, 11′, 22′, . . . **YY′** perpendicular to **OY**.

Through **a**, **b**, . . .**e** draw lines parallel to **OY**.

With centre 1′ and radius 0′**G** ($1\frac{1}{2}''$) cut the parallel through **e** giving the point **E** on the cycloid.

Carry out a similar construction with centres 2′, 3′, 4′, 5′, cutting the parallels through **d**, **c**, **b**, **a**, and so obtain the further points, **D**, **C**, **B**, **A**, on the cycloid.

Draw a smooth curve through these points giving the semi-cycloid **YABCDEG**.

The other half of the cycloid may be obtained by similar constructions to the left of **OG** or by the use of tracing paper.

EPICYCLOID

To draw an epicycloid when the generating circle and the director are given, Fig. 147.

Let the generating circle **GO** be 3″ diameter and the arc **XY** of a 10″ diameter circle be the director.

H is the centre of the director circle.

Join **HO** and produce to **G**, the generator.

Make arc **OY** equal to one-half the circumference of the generating circle (1.5π ins.).

This may be found by calculating the angle subtended by this arc at the centre **H** :

$$Y\hat{H}O^\circ : 180^\circ : : \pi O'G : \pi HO\,;$$

$$\therefore\ Y\hat{H}O^\circ = \frac{180^\circ \times \pi O'G}{\pi HO} = \frac{180 \times 1\frac{1}{2}''}{5''} = 54^\circ.$$

Divide the semi-circle on **OG** into a number of equal parts (say 6) giving the points **a**, **b**, . . . **e**.

Divide **OY** into the same number of equal parts giving the points 1, 2, . . . 5.

With centre **H** and radius **H0′** draw the arc **O′Y′** concentric with **OY**. (*This arc will be the path of the centre* 0′ *of the generating circle as it rolls on the director.*)

With centre **H** draw similar concentric arcs starting at the points **a**, **b**, . . . **e**.

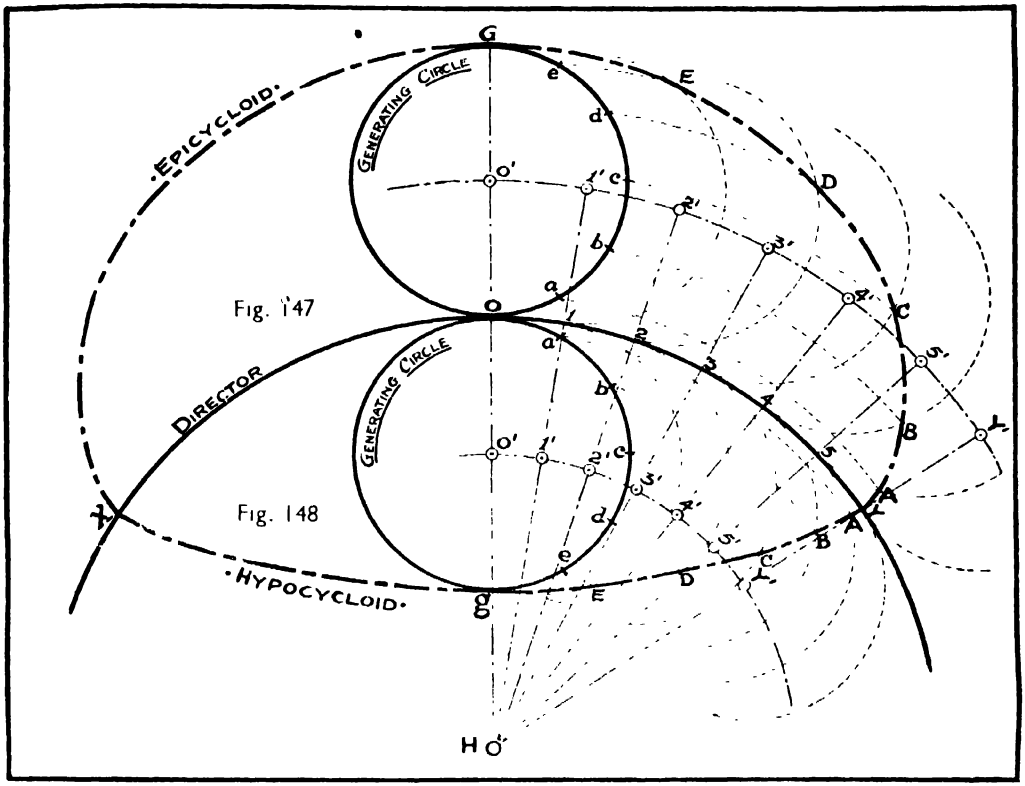
Draw the radii **H1**, **H2**, . . . **HY** and produce them to meet the arc 0′**Y′** in the points 1′, 2′, . . . **Y′**.

With centre 1′ and radius 0′**G** (1½″) cut the arc from **e** giving the point **E** on the epicycloid.

Carry out a similar construction with centres 2′, 3′, 4′, 5′, cutting the arcs from **d**, **c**, **b**, **a**, and so obtain the further points **D**, **C**, **B**, **A**, on the epicycloid.

Draw a smooth curve through these points giving the semi-epicycloid **YABCDEG**.

The other half of the epicycloid may be obtained by similar constructions to the left of **OG** or by the use of tracing paper.



HYPOCYCLOID

To draw a hypocycloid when the generating circle and the director are given, Fig. 148.

Let the generating circle **gO** be 3″ diameter and the director be the same as in Fig. 147.

g is the generator.

The construction for obtaining the points on the hypocycloid is exactly similar to that used for the epicycloid. Respective points have been similarly marked so that the method can be easily followed on the figure.

When **gO** **HO** (i.e., diameter of generating circle radius of director), the hypocycloid becomes a straight line.

INVOLUTE

This is a particular case of the epicycloid. If a flexible cord be kept taut and is unwound from a circle, in the plane of the circle, the end of the cord will describe the curve called the involute of the circle, Fig. 149

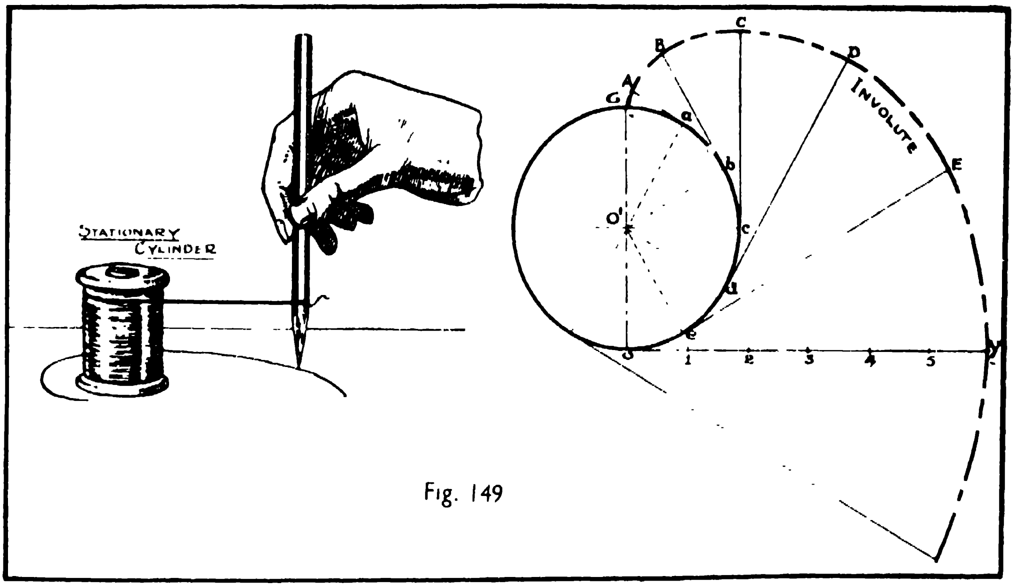


Fig. 149

To draw the involute curve of a given circle, Fig. 149.

Let 0G (3″) be the diameter of a circle, whose generator is **G**.

Draw 0**Y** equal to one-half the circumference of the circle (1.5π ins.) and tangential to it at the point 0.

Divide the semi-circle on 0**G** into a number of equal parts (say 6) giving the points **a**, **b**, . . . **e**.

Divide 0**Y** into the same number of equal parts (6) giving the points 1, 2, . . . 5.

Draw tangents to the circle at the points **a, b**, . . . **e.**

On these tangents cut off **aA** 01, **bB** 02, **cC** 03, **dD** 04, **eE** 05.

Draw a smooth curve through these points for the involute curve, which may be extended to any length by continuing in the same manner.

SPIRALS

The spiral is a plane curve traced by a point as it winds about and recedes from (or approaches to) a fixed point, called its centre, according to some law or definite proportion.

Pole : The centre (or "*eye*") of the spiral about which the curve rotates.

Radius Vector : The straight line between any point on the spiral and the pole.

Convolution : One complete revolution of a point on the spiral.

ARCHIMEDEAN SPIRAL

An **Archimedean spiral** is the locus of a point which moves towards, or away from, a fixed point by **equal amounts** measured along the radius vectors taken in order (said to be in a series of *Arithmetic Progression*).

To draw an Archimedean spiral of two convolutions from the pole O with the longest vector OA (2″), Fig. 150.

Through **O** draw radii making equal angles (say 60) between them, thus dividing the total angle swept out by the vector into six equal parts.

Divide **OA** into two equal parts at **B** (number of convolutions required).

On the radii **0.1, 0.2, 0.3 - - - 0.12** set the corresponding distances **0.1′, 0.2′, 0.3′ - - - - - - 0.12** giving the points $\mathbf{P^1}$, $\mathbf{P^2}$, $\mathbf{P^3}$ - - - $\mathbf{P^{12}}$ and commencing at **O**, draw a smooth curve through these points to obtain the spiral.

If you have studied the movement of a watch, you will have noticed the small spring (similar to this spiral) which controls the movement of the balance wheel as it oscillates backwards and forwards.

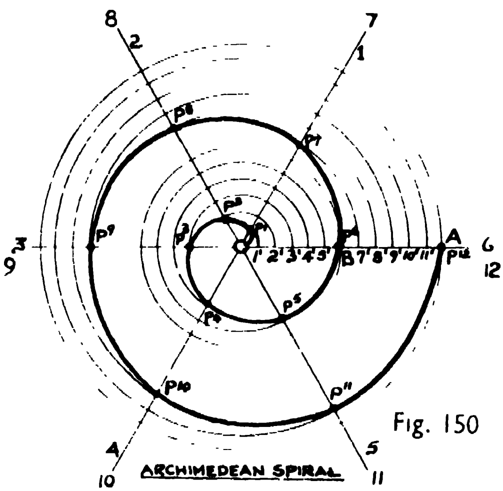


Fig. 150

Note : Archimedes was a famous Greek mathematician who was born in 287 BC and you will no doubt have heard about him in the Science room in connection with the Principle of Archimedes.

LOGARITHMIC SPIRAL

A Logarithmic spiral is the locus of a point which moves towards, or away from, a fixed point so that there is a constant ratio between the lengths of the radius vectors taken in order (said to be in *Geometrical Progression*).

To draw a logarithmic spiral of one convolution, giving the shortest radius vector ($\frac{1}{2}''$) and the ratio (5 : 6) of the radius vectors with an angle of 30°, Fig. 151.

Through **O** draw radii **O.1, O.2, O.3** - - - - - **O.12** making equal angles of 30° between them.

Draw **O′A** and **O′B** with the contained angle of 30° (Fig. 151A).

Set off **O′P′** ($\frac{1}{2}''$) the given radius vector and **O′C** = $\frac{6}{5}$**O′P′**($\frac{6}{5} \times \frac{1}{2}''$).

Join **P′C**.

With centre **O′** and radius **OC** describe an arc cutting **O′B** in **1′**.

Draw **1′d** parallel to **P′C**.

With centre **O′** and radius **O′d** describe an arc cutting **O′B** in **2′**.

Draw **2′e** parallel to **1′d**.

Continue this construction to obtain the remaining points **3′, 4′** - - - **12′** on **O′B**.

Set off the distances **O′1′, O′2′, O′3′** - - - - **O′12′** on the corresponding radius vectors (Fig. 151) to obtain **P^1, P^2, P^3** - - - **P^{12}** and commencing at **P**, draw a smooth curve through these points to obtain the spiral.

SEMI-CIRCULAR SCROLL

To draw a spiral scroll by the method of continuous semi-circles, Fig. 152.

Let **AB** (3″) be the limit of a scroll of three convolutions.

Divide **AB** into a number of equal parts (say 6).

With **O** as centre describe a semi-circle on 3-4.

With centre 3 and radius 3-4 describe semi-circle on 4-2.

Using **0 and 3** as centres alternately continue the semi-circles as shown in the figure.

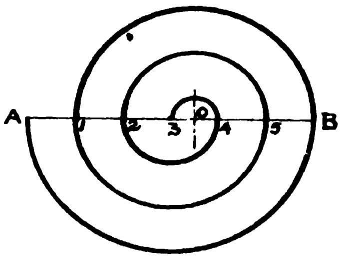


Fig. 152

SCROLL OF SEMI-CIRCULAR ARCS

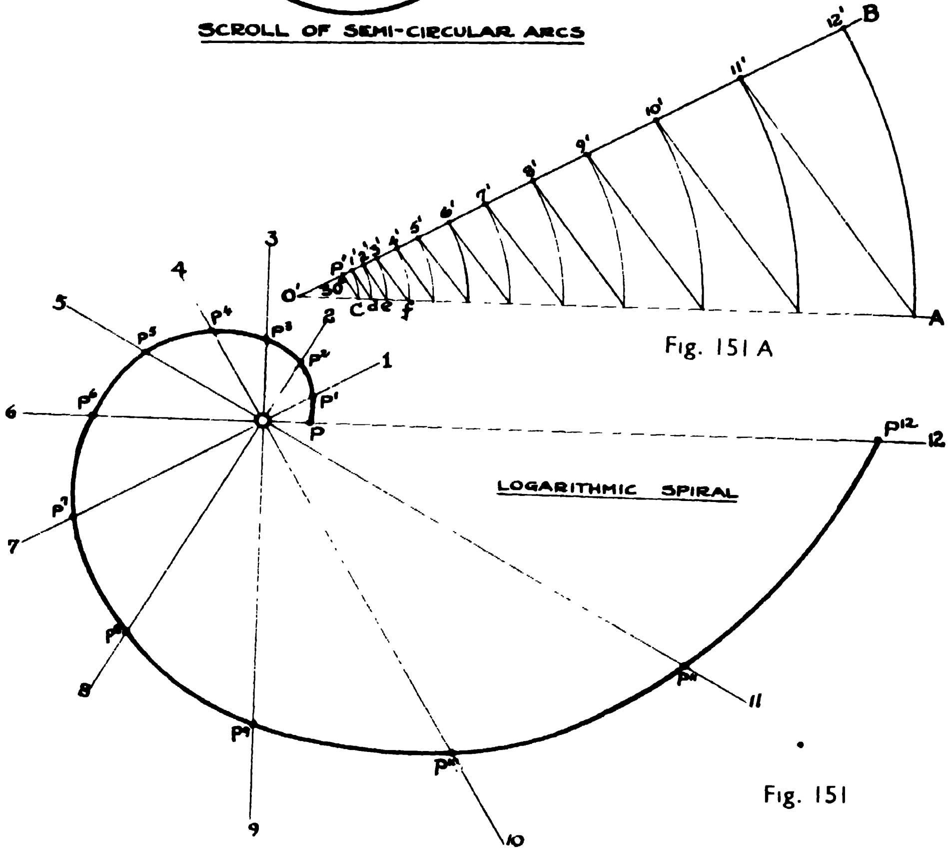


Fig. 151 A

Fig. 151

HELIX — PLATE 36

A helix is the path traced out by a point as it moves, with uniform velocity, along the surface of a cylinder, or cone, so that it twists as it rises (or falls), e.g., as you would ascend (or descend) a spiral staircase.

Pitch : This is the distance, measured parallel to the axis, during one revolution (or turn) and is sometimes referred to as the " lead."

CYLINDRICAL HELIX

Fig. 153 shows a cylindrical helix because the path is on the surface of a cylinder, e.g., cylindrical coil spring, screw thread on a bolt or simply winding a thread round a piece of circular wood (pencil).

To draw a cylindrical helix, Fig. 153.

Draw the plan (2″ diameter), divide the circle into twelve equal parts **0, 1, - - - - 12** and project these points to the elevation.

Mark off the pitch ($1\frac{1}{2}$″), divide this distance into the same number of equal parts (12) and draw horizontal lines through them.

Where the vertical line from **1** and **11** (plan) meets the correspondingly numbered horizontal lines (elevation) will fix two points (**1′** and **11′**) on the helix.

Other points can be found in the same way as shown in the figure.

Draw a smooth curve through the twelve points showing the helix for one complete turn.

Note : *The surface development for this part of the cylinder would show the path of the helix as the hypotenuse of a right angled triangle with cylinder circumference as base, and the pitch as vertical height* (*Fig.* 153A).

CONICAL HELIX

Fig. 154 shows a conical helix because the path is on the surface of a cone, e.g., the path travelled is around a cone-shaped surface. The sketch of an amusement (the "helter-skelter") often seen in a fun fair is shown, Fig. 155, where the slide is that of a conical helix.

To draw a conical helix, Fig. 154.

Draw the plan (3″ diameter), divide the circle into twelve equal parts (**0, 1, - - - 12**) and project to the base of the cone.

Join these points from the base to the apex **P**.

Mark off the pitch ($2\frac{1}{2}$″), divide this distance into the same number of equal parts (12) and draw horizontal lines through them across the surface of the cone, giving the points **0′, 1ᴾ, 2ᴾ, - - - - 12ᴾ**.

With centre **P** and radius **PO′** draw the arc **0′, 1, 2, - - - - 12,** which is divided into 12 equal parts (distance 0-1 from the plan will be near enough for each part) and join these points to **P** giving **P1, P2, - - - - - - P12.**

With **P** as centre draw the arcs from **P.O′, P.1ᴾ, P.2ᴾ, - - - - P.12ᴾ**.

Mark the points of intersection between the arcs from **1ᴾ, 2ᴾ, - - - - - P12ᴾ, 12ᴾ**, and the corresponding lines **P1, P2, - - - P12** and join them with a smooth curve to obtain the path of one turn of the helix on the surface of the cone (**0′**, $\mathbf{1_1}$, $\mathbf{2_1}$, $\mathbf{3_1}$, . . . $\mathbf{12_1}$).

Can you plot these points on the plan to give a spiral representing that view of the helix as shown by the broken line?

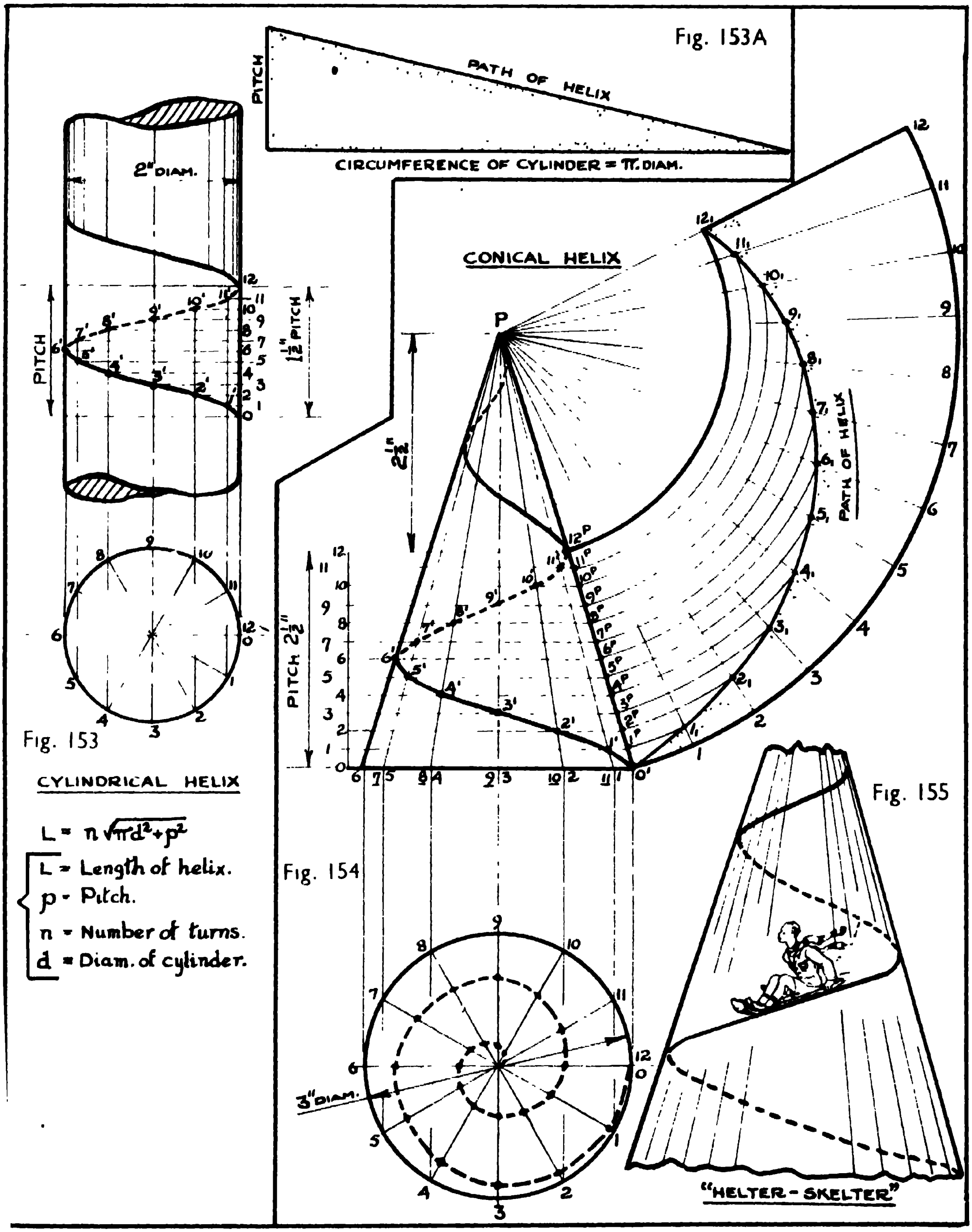


Fig. 153A

Fig. 153

CYLINDRICAL HELIX

$L = n\sqrt{\pi d^2 + p^2}$

- L = Length of helix.
- p = Pitch.
- n = Number of turns.
- d = Diam. of cylinder.

Fig. 154

Fig. 155

IRREGULAR OR "FRENCH" CURVES

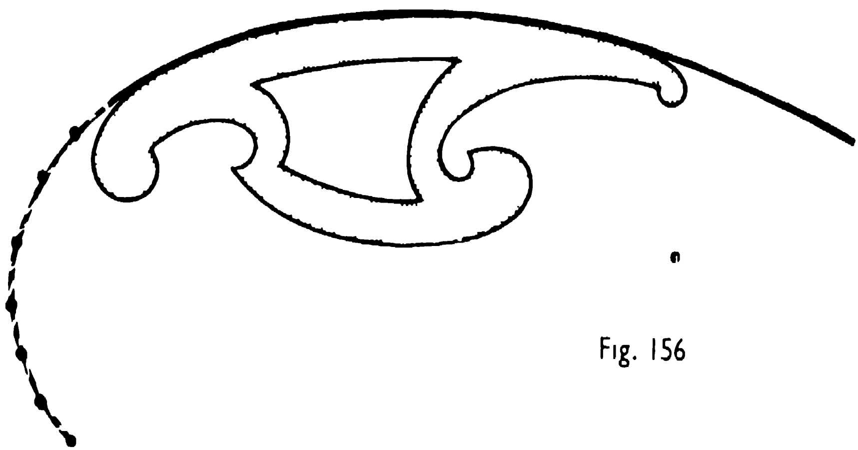


Fig. 156

When the required curves are not arcs of a circle, a "French Curve" is used as a "*template*" for the particular curve. "French Curves" are instruments, usually made of material similar to that used for set squares, and are in sets. A set consists, primarily, of portions of the mathematical curves, e.g., ellipse, parabola, hyperbola, involute, etc., and the remainder of the set is made up of curves most frequently met with in a particular vocation, e.g., railway curves, yachting curves, architectural curves, etc.

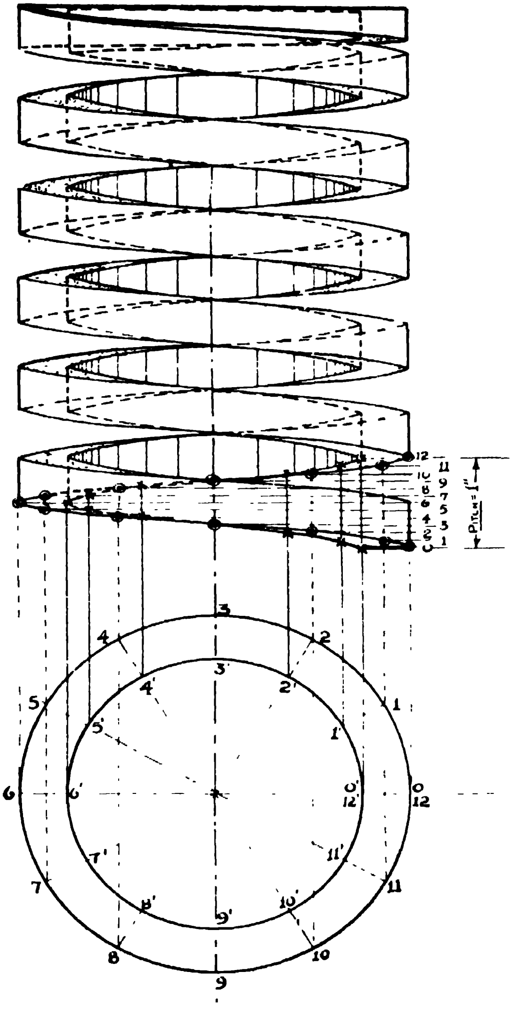
The method of using the French Curve is to align it along the required curve or part of it. The track of the curve is first plotted by a series of dots through which a free-hand approximation of the irregular curve is drawn. A suitable curve is selected so that a portion of it fits part of the free-hand curve and this is drawn in. The procedure is repeated by moving the curve (or another one if more suitable for the purpose) until the irregular curve has been completed (Fig. 156). It is important to ensure that each new stage should commence by matching the latter portion of the previous position so that the final curve will be a "*smooth*" line through the points.

PLATE 37

EXERCISE 30 —

Use half 22" · 11" paper

To draw a coil spring having an internal diameter of say 3", a pitch of say 1", and made from say ½" × ½" tempered steel.



Draw the plan consisting of two concentric circles (3" and 4" diam.).

Divide these circles into any number of equal parts (say 12), giving the points **0, 1, 2, - - - 12** and **0′, 1′, 2′,** - - - 12′.

Set up the pitch (1") and divide this into the same number of equal parts (**12**) giving the points **0, 1, 2, - - - 12.**

Draw horizontal lines through these points.

At the point of intersection, between the vertical projector from the point **1** in the plan and the horizontal line through the point **1** in the elevation, is a point on the helical curve representing the outside of the coil.

Similar points (indicated thus O) are obtained by projections from the other points **2, 3, - - - 12** in the plan.

Draw a smooth curve through the points marked O.

The helix for the inside of the coil is determined in the same way by projecting from the points **0′, 1′, 2′, - - - - 12′,** and may be easily followed on the drawing. These points are indicated thus **X**.

Obviously the helical path of the inside of the coil will not coincide with that for the outside, because these paths are of different lengths, while the pitch remains the same. Further, the space between the coils on one side of the elevation will correspond to the depth of the coil itself on the opposite side of the spring in the same view.

The curves representing the other coils on the spring can now be plotted with the help of tracing paper.

The elevation is finished at the top and base with a half pitch and a half coil, as the spring must have a horizontal bearing surface at these places.

CHAPTER 5

RIVETS — RIVETED JOINTS — ROLLED STEEL SECTIONS — JOINTS IN STEEL WORK — SCREW THREADS — GEAR WHEELS — WHEEL TEETH

RIVETS AND RIVETED JOINTS

In constructional work it often happens that we require to join two pieces of metal securely together. There are two well-known methods of doing this. The first is the *Bolt-and-Nut method* already described in Part 1 ; the other is the *method of Riveting.*

Although these methods are somewhat similar there is an important difference between them. A joint by **bolt and nut** can be **undone** at any time **without damage** to the bolt, the nut or the pieces joined; but a fastening by **rivets** is **permanent** and **cannot be separated** without destroying the rivets.

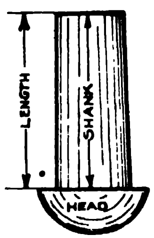


Fig. 157

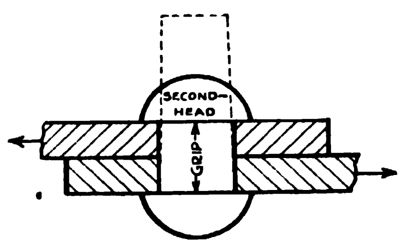


Fig. 158

Rivets. A rivet is a cylindrical piece of metal with a *head* formed on it (Fig. 157). When two pieces of metal are to be riveted together, a rivet of the same metal as the pieces to be joined is generally used.

Riveting. The operation of joining two, or more, metal plates together by means of rivets is called riveting. Rivets are satisfactory only when they are in shear.* The plates have corresponding holes punched or drilled in them. The diameters of the holes are a little larger than the diameter of the rivet to be used. Riveting is best done by a riveting machine, but where this is not possible riveting by hand is resorted to. In both methods the rivet is heated to redness and inserted into the holes in the plates, which have already been *lined up* ready for riveting. To facilitate the easy insertion of the rivet into the hole, the shank is slightly tapered from the head towards the end (Fig. 157). In the machine riveting the projecting shank of the rivet is pressed to form a second head (Fig. 158) by compressed air, hydraulic or steam pressure. The whole operation is a matter of seconds and hundreds of rivets may be driven in an hour. In riveting by hand, the projecting shank is shorter and the second head is formed by hand hammering. A cup-like tool, called a "*dolly*," is held against the rivet head by way of reaction pressure, while riveting is being carried out.

It is important that the shank of the rivet, after it has been driven, should completely fill the hole in the plates. Machine riveting of steel plates may be carried out *cold*, i.e., without heating the rivets ; but it requires much more power to drive the rivets *cold* as it does when they have been heated. Riveting of the softer metals, e.g., copper, brass and tin, is carried out *cold*.

* NOTE ON TENSION AND SHEAR. In the particular case of a boiler constructed of overlapping plates, the steam pressure inside tends to pull the overlapping plates away from one another. This is what is meant by saying the plates are in *tension*. The rivets at the same time tend to be *shorn* through ; they are said to be in *shear*.

Proportions of Rivet Heads. The proportions of various rivet heads, in terms of rivet diameter (**D**), are shown in Figs. 159, 160, 161. When a number of rivets have to be shown on a drawing, the proportions given in Fig. 162 are considered near enough for practical drawing purposes.

Rivet Diameter. This is the maximum diameter of the rivet. Rivets are standardised according to the length of the shank and the maximum diameter ($\frac{1}{16}''$ to $1\frac{1}{4}''$).

Rivet Pitch. The distance from the centre to centre of adjacent rivets in the same row is called the *pitch* (Figs. 163, 164).

Margin. The shortest distance from the outer edge of the plate to the edge of the rivet hole in the plate is called the *margin.* This distance should not be less than the rivet diameter (Fig. 163).

Lap. The amount by which one plate overlaps the other in a lap joint is called the *lap.*

RIVETED JOINTS

Riveted Joints. Riveted joints are classified under two groups—**Lap Joints** and **Butt Joints.**

Lap Joints. A lap joint is formed when the two plates to be joined overlap each other and are held together by one or more rows of rivets.

Butt Joints. A butt joint is formed when the two plates to be joined are securely held in the same plane by two straps of metal placed on opposite sides of the joint, the whole being riveted together with one or more rows of rivets.

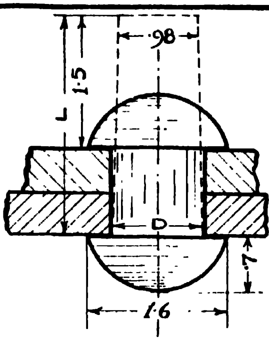
Lap and butt joints are again subdivided according to the number of rows of rivets in the joint.

Single-Riveting consists of one row of rivets in a lap joint or one row of rivets on each side of a butt joint (Fig. 163, 165).

Double-Riveting consists of two rows of rivets in a lap joint or two rows on each side of a butt joint (Figs. 164, 166). Rivets may be driven " *zig-zag* " (Fig. 166) or " *chain* " (Fig. 165).

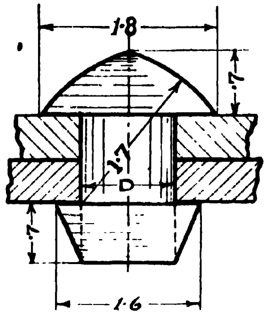
Single-Riveted Lap Joint. Fig. 163 shows the approximate proportions, in terms of **D** (the rivet diameter), of a single-riveted lap joint.

Double-Riveted Lap Joint. Fig. 164 shows a double-riveted lap joint and its proportions.



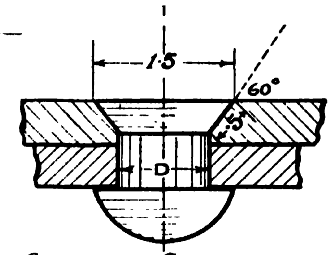
CUPHEAD AND CUPHEAD

Fig. 159



PAN HEAD AND CONICAL HEAD

Fig. 160



CUPHEAD AND COUNTERSUNK

Fig. 161

PROPORTIONS FOR DRAWING PURPOSES

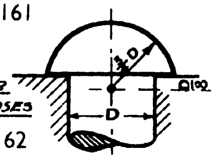
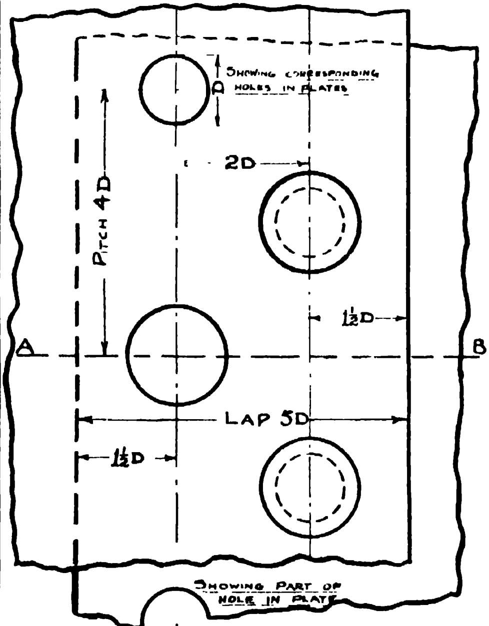
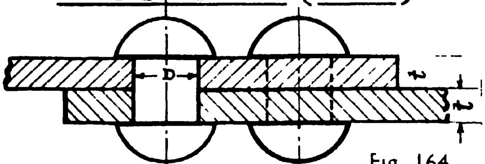


Fig. 162

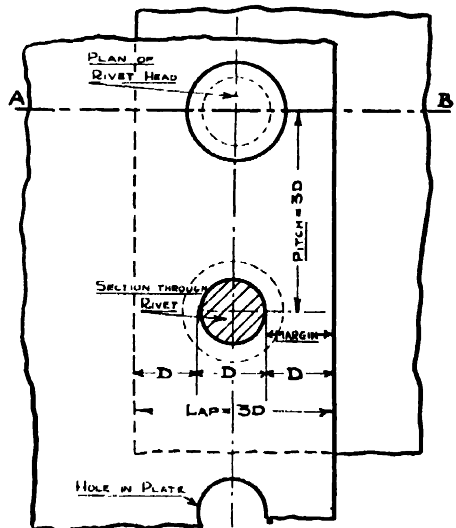


DOUBLE LAP JOINT (ZIG-ZAG)



SECTION A–B

Fig. 164



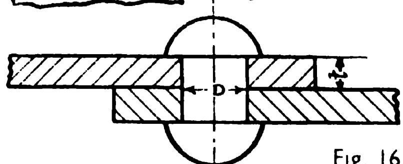


Fig. 163

SECTION A–B
SINGLE LAP JOINT

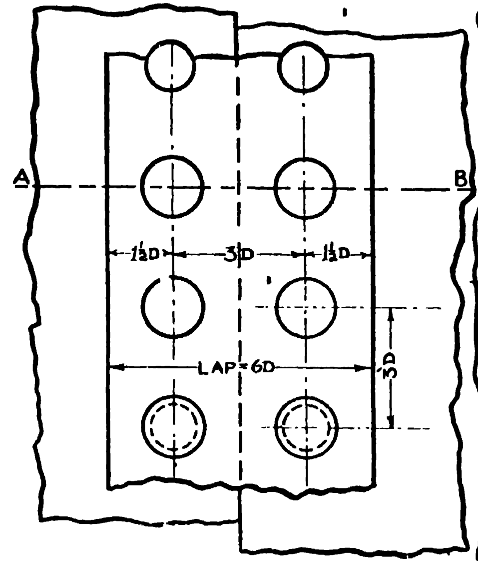
Single-Riveted Butt Joint. Fig. 165 shows a single-riveted butt joint, with two cover plates and the proportions of the joint. The thickness of each cover plate may be taken as $\frac{3}{4}$**t**, where **t** is the thickness of the plates being joined.

Double-Riveted Butt Joint. Fig. 166 shows a double-riveted butt joint with two cover plates.

Joining Plates which meet at an angle. Fig. 167 shows the *flanging* method of joining two plates meeting at an angle. Fig. 168 shows the application of an *angle section* to join two plates at right angles.

EXERCISE 31 — Use 22″ · 15″ paper — **PLATES 38 and 39**

1. Make accurate drawings of the various forms of rivet heads to the proportions given in Figs. 159, 160, 161. Allow for plates $\frac{5}{8}$″ thick, and a rivet diameter of 1″.
2. Draw, to a scale of full size, the plan and the section of a single-riveted lap joint (Fig. 163), showing three or four rivets. The plates are $\frac{3}{8}$″ thick and the rivets $\frac{5}{8}$″ diameter.
3. Draw, to a scale of $\frac{3}{4}$ full size, the plan, showing two or three pitches, and the section of a double-riveted lap joint (Fig. 164). The plates are $\frac{1}{2}$″ thick and the rivets $\frac{3}{4}$″ diam.
4. Draw, to a scale of full size, the plan of three pitches, and section of a single-riveted butt joint (Fig. 165). The plates are $\frac{5}{16}$″ thick and the rivets $\frac{5}{8}$″ diameter.
5. Draw, to a scale of $\frac{1}{2}$ full size, the plan and section of a double-riveted butt joint with two cover plates, similar to that shown in Fig. 166. The plates are $\frac{5}{8}$″ thick and the rivets 1″ diameter.
6. Draw, to a scale of full size, the section of an obtuse-angled flanged joint similar to that in Fig. 167. The plates are $\frac{3}{8}$″ thick. Fix the pitch of the rivets and add a plan showing three pitches (scale, full size). Use $\frac{5}{8}$″ rivets.
7. Draw, to a scale of $\frac{3}{4}$ full size, the section and plan of three pitches of a right-angled joint (Fig. 168), using 3″ · 3″ · $\frac{1}{4}$″ *angle iron*. The plates are $\frac{3}{8}$″ thick and the pitch is **4D**. Particulars of the angle iron and size of rivets to be used will be found in the table on page 130.
8. Write down examples of three objects which are riveted and three which are put together with bolts and nuts.



SINGLE BUTT JOINT (CHAIN)

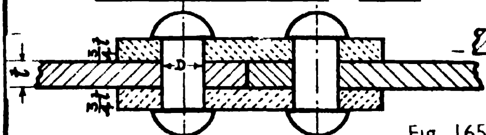
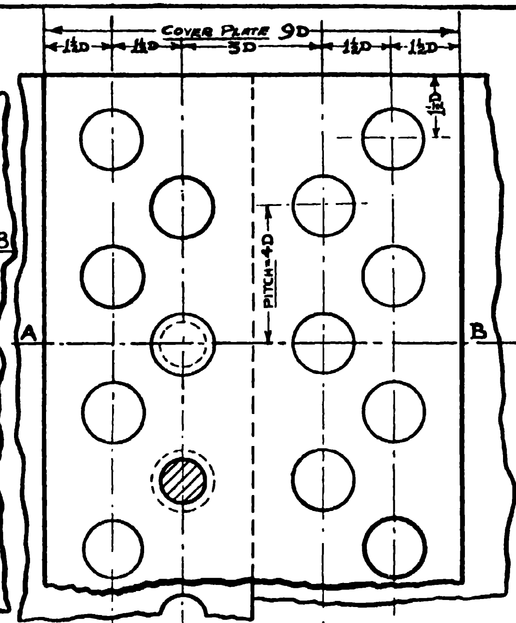
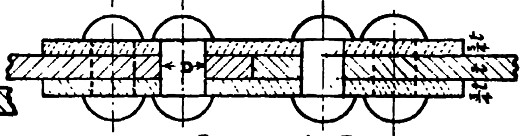


Fig. 165

SECTION A–B



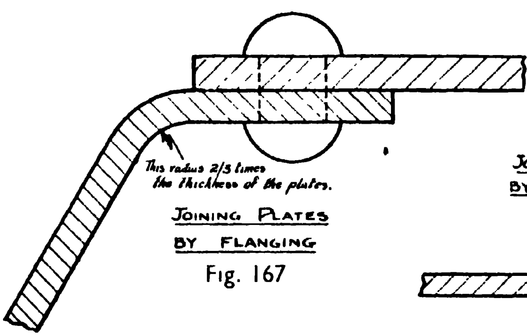


SECTION A–B

Fig. 166

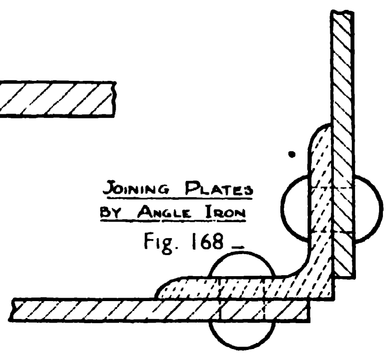
DOUBLE BUTT JOINT

(ZIG–ZAG)



JOINING PLATES BY FLANGING

Fig. 167



JOINING PLATES BY ANGLE IRON

Fig. 168

ROLLED STEEL SECTIONS

Plate 40 (page 131) shows the proportions of the common rolled steel sections. These sections have been designed to give the maximum of strength for the minimum of material. Lengths of steel (up to 40 or 50 feet long) rolled to these sections are extensively used in all kinds of constructional work.

ROUND SECTION, Fig. 170. This section is divided into three groups for practical purposes, viz., **wire, rod,** and **round bar** :

Wire. When the diameter is small, the round section is referred to as *wire*. The diameter of wires is measured by means of a gauge as this measurement is too small to be taken accurately by any other means. One type of gauge is shown in Fig. 169 and is known as the Standard Wire Gauge (S.W.G.). The size of wire is known by the number of the slot into which the wire fits, e.g., a "No. 10 S.W.G. wire" means that the diameter of this wire is equal to the width of the slot opposite No. 10 on the Standard Wire Gauge.

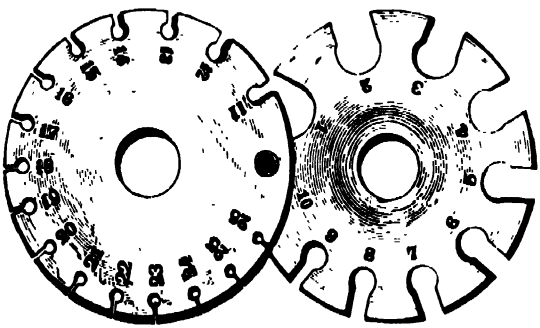


Fig. 169

Rod. A round section is referred to as *rod* when the diameter ranges from $\frac{1}{4}''$ to $1\frac{1}{2}''$, increasing by $\frac{1}{16}''$. Rods are stocked in *random* lengths varying between $13'$ and $18'$.

Round Bar. A round section is referred to as *round bar* when the diameter ranges from $1\frac{1}{2}''$ to $12''$ and over. Round bars are generally used for machine shafting.

FLAT SECTION, Fig. 171, Plate 40. This section is divided into three groups for practical purposes, viz., **sheet-metal, plate** and **flat bar** :

Sheet-metal. As in the case of wire, the thickness of thin metal sheet is measured by means of a gauge. Brass and copper sheet are measured by the S.W.G., while zinc has a gauge for itself. Iron sheet is measured by the Birmingham Gauge (B.G.), and is stocked in sheets $6'$ and $7'$ long, and from $12''$ to $48''$ wide. The table opposite gives the **actual** thickness of iron sheet and a comparison between the S.W.G. and B.G. in thousandths of an inch.

Plate. Flat steel sheet of thickness $\frac{3}{16}''$ to 1″, and of width 12″ to 80″, is referred to as *steel plate.*

Flat Bar. This steel strip, $\frac{1}{2}''$ to 6″ broad and of thickness varying between 10 B.G. and 26 B.G., is known as *steel hoop*. Standard flat bars have thickness varying from $\frac{1}{4}''$ to 1″ and breadth from 1 to 12″.

SQUARE SECTION, Fig. 172, Plate 40. This section may be obtained in sizes from $\frac{3}{16}''$ to 12″ side of square. When **S** exceeds 3″ or thereby it is more economical, and in most cases quite suitable, to use one of the sections, I, T, L, [, according to the purpose required.

No. on Gauge	S.W.G. Ins.	B.G. Ins.	Approximate Actual Thickness Represented B.G.
0	·324 app. $\frac{5}{16}''$	·396	
1	·300	·353	
2	·276	·314	
3	252 app. $\frac{1}{4}''$	·280	
4	·232	·25	
5	·212	·222	
6	·192 app. $\frac{3}{16}''$	·198	
7	·176	·176	
8	·160	·157	
9	·144	·139	
10	·128 app. $\frac{1}{8}''$	·125	

No. on Gauge	S.W.G. Ins.	B.G. Ins.	Approximate Actual Thickness Represented B.G.
11	·116	·111	
12	·104	·099	
13	·092	·088	
14	·080	·078	
15	·072	·069	
16	·064 app. $\frac{1}{16}''$	·062	
17	·056	·055	
18	·048	·049	
19	·040	·044	
20	·036	·039	
21	·032 app. $\frac{1}{32}''$	·034	
22	·028	·031	
23	·024	·027	
24	·022	·024	
25	·020	·022	
26	·018	·019	
27	·016	·017	
28	·014	·015	

H OR I, TEE, ANGLE, AND CHANNEL SECTIONS. The undernoted tables give the standard particulars for a few of each of these sections. Those selected are such as appear in the drawing exercises which follow.

H OR I SECTION. FIG. 173

D × B	t_1	t_2	r_1	r_2	s	d	Wt. per foot.
14″ × 8″	·46	·92	·77	·38	4·5	$\frac{3}{4}$″	70 lbs.
12″ × 6″	·40	·72	·50	·25	3·5	$\frac{3}{4}$″	44 ,,
8″ × 6″	·35	·65	·61	·30	3·5	$\frac{3}{4}$″	35 ,,
6″ × 3″	·25	·40	·41	·20	1·5	$\frac{1}{2}$″	12 ,,

TEE (T) SECTION. FIG. 174

B × D	t	r_1	r_2	s	d	Wt. per foot.
6″ × 4″	·50	·42	·29	3·5	$\frac{7}{8}$″	16·22 lbs.
4″ × 3″	·50	·33	·23	2·25	$\frac{3}{4}$″	11·09 ,,
3″ × 3″	·375	·30	·21	1·5	$\frac{1}{2}$″	7·21 ,,

EQUAL AND UNEQUAL ANGLE (L) SECTION. FIG. 175

D × B	t	r_1	r_2	s	s_1	d	Wt. per foot.
5″ × 5″	·50	·42	·29	2·00	1·75	$\frac{3}{4}$″	16·16 lbs.
6″ × 3″	·375	·39	·27	2·25	2·25	$\frac{3}{4}$″	11 ,,
4″ × 3″	·375	·33	·23	2·25	—	$\frac{3}{4}$″	9.5 ,,
3″ × 3″	·25	·30	·21	1·75	—	$\frac{5}{8}$″	4·9 ,,

CHANNEL ([) SECTION. FIG. 176

D × B	t_1	t_2	r_1	r_2	s	d	Wt. per foot.
9″ × 3″	·30	·44	·48	·24	1·75	$\frac{3}{4}$″	17·46 lbs.
7″ × 3″	·26	·42	·48	·24	1·75	$\frac{3}{4}$″	14·22 ,,
4″ × 2″	·24	·31	·36	·18	1·125	$\frac{5}{8}$″	7·09 ,,

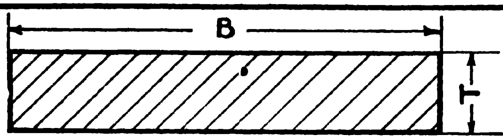
Note: The column **d** in the above tables gives a suitable size of rivet or bolt.

EXERCISE 32 — Use 22″ × 15″ paper — PLATE 40

Draw, to a scale of full size, the following rolled steel sections, whose dimensions will be found from the above tables:

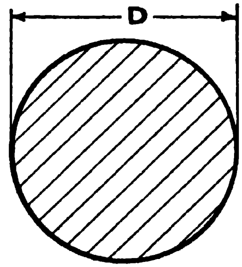
8″ × 6″ H section. 6″ × 4″ **Tee** section.

5″ × 5″ **Angle** section. 9″ × 3″ **Channel** section.



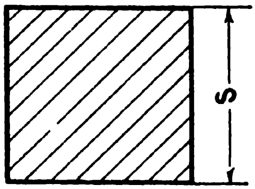
• FLAT • SECTION •

Fig. 171



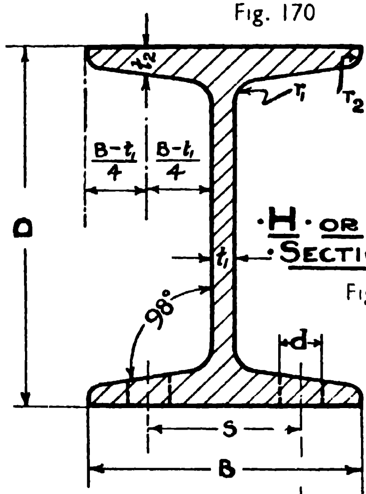
• ROUND • SECTION •

Fig. 170



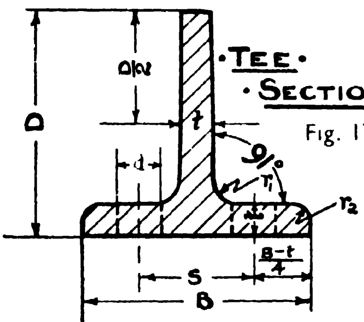
• SQUARE • SECTION •

Fig. 172



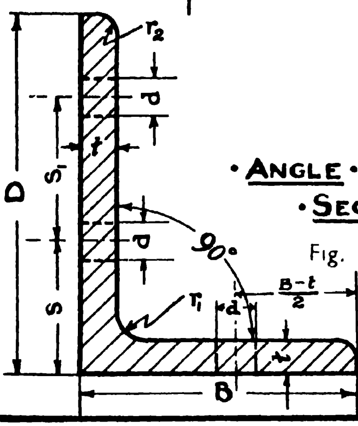
• H • OR • I •
• SECTION •

Fig. 173



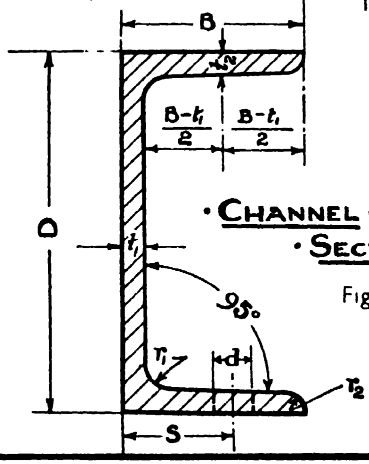
• TEE •
• SECTION •

Fig. 174



• ANGLE •
• SECTION •

Fig. 175



• CHANNEL •
• SECTION •

Fig. 176

EXERCISE 33 — Use 22″ × 15″ paper — PLATE 41

Fig. 177 shows the method of joining two H sections by means of a *fishplate* placed on each side of the web. Draw, to a scale of $\frac{3}{4}$ full size, the given elevation and end view. (*The method is similar to that employed in connecting two lengths of railway line.*)

Fig. 178 shows a method of fixing various members, meeting at the apex of a steel roof, by means of a *gusset* plate. Draw, to a scale of $\frac{1}{2}$ full size, the plan, elevation, and end view, to the dimensions given.

Fig. 179 shows the method of combining, by the use of bracing plates, two H sections to form one member. Make a neat sketch of this in your sketch book ; then prepare an isometric drawing to a scale of $\frac{1}{3}$ full size.

Figs. 180 and 181 show methods of joining steel sections, meeting at right angles, by means of angle plates. Copy these figures into your sketch book and draw to a scale of $\frac{1}{2}$ full size, an elevation and end view.

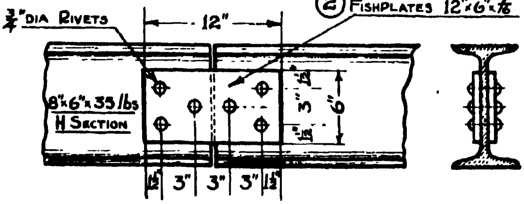


Fig. 177

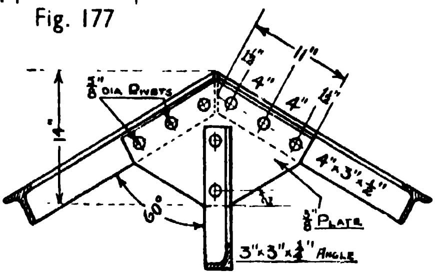


Fig. 178

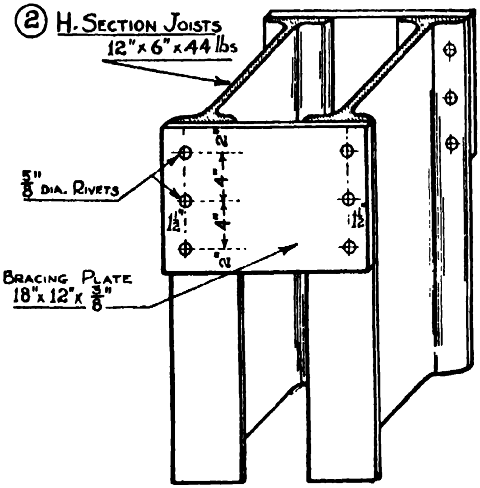


Fig. 179

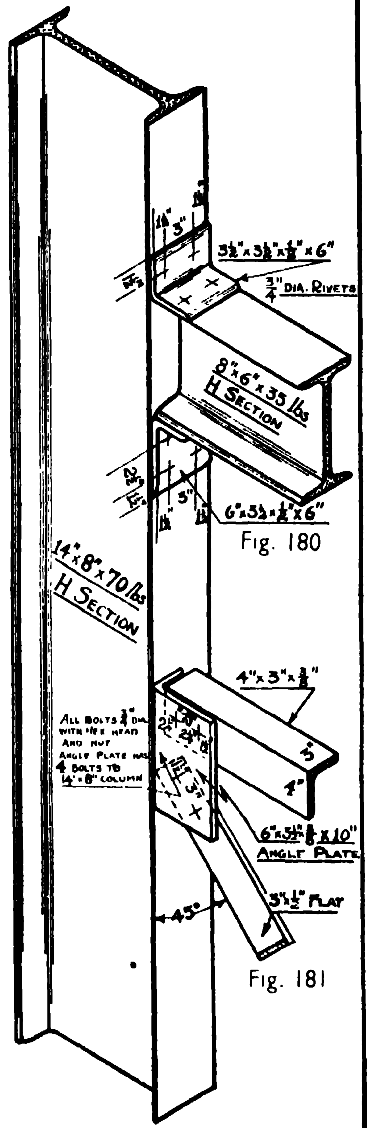


Fig. 180

Fig. 181

SCREW THREADS

When a continuous groove is cut on a cylinder a *screw* is formed. The solid ridge of material, which is left between the grooves, is called the *thread*, and the cylinder is said to have a *screw thread* cut upon it. A screw thread has a very definite form and its path is that of a *helix*, i.e., the thread passes not only round the cylinder, but also along it, in the direction of the cylinder axis (Fig. 188).

Screw threads are used for two purposes :

(1) As a fastening and fixing for separate parts, so that they can be disconnected when required. **Vee threads** are used for this purpose.

(2) As a means of transmitting motion. **Square threads** are used for this purpose.

Thread Form. This is the shape of the section of a thread as seen on a plane containing the axis of the screw.

Thread Pitch. This is the distance from any point on the *crest*, or on the *root*, of a thread to the corresponding point on the next turn of the same thread, measured parallel to the axis.

Right and left-hand Screws. A screw is referred to as "*right-hand*," if when turned in a *clockwise* direction, it enters the work in a direction *away from the operator*. A screw which enters the work when turned in an *anti-clockwise* direction is referred to as "*left-hand*."

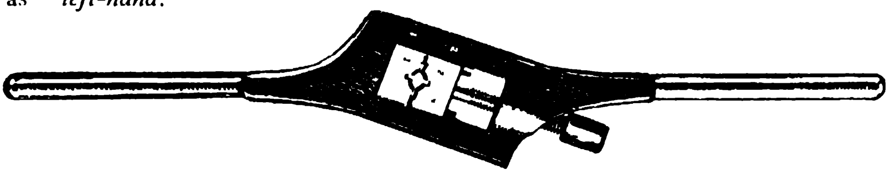
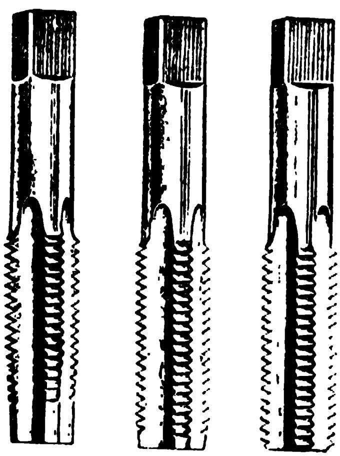


Fig. 186 HAND STOCKS AND DIES.

External vee threads are cut by hand *stocks and dies* (Fig. 186), by special screwing machine, or in a lathe.

Internal vee threads are cut by *screw taps* (Fig. 187) or in a screw-cutting machine.

Square and special threads are cut in a lathe with a sharp-pointed tool.



TAPER INTERMEDIATE PLUG
Fig. 187—SCREW TAPS.

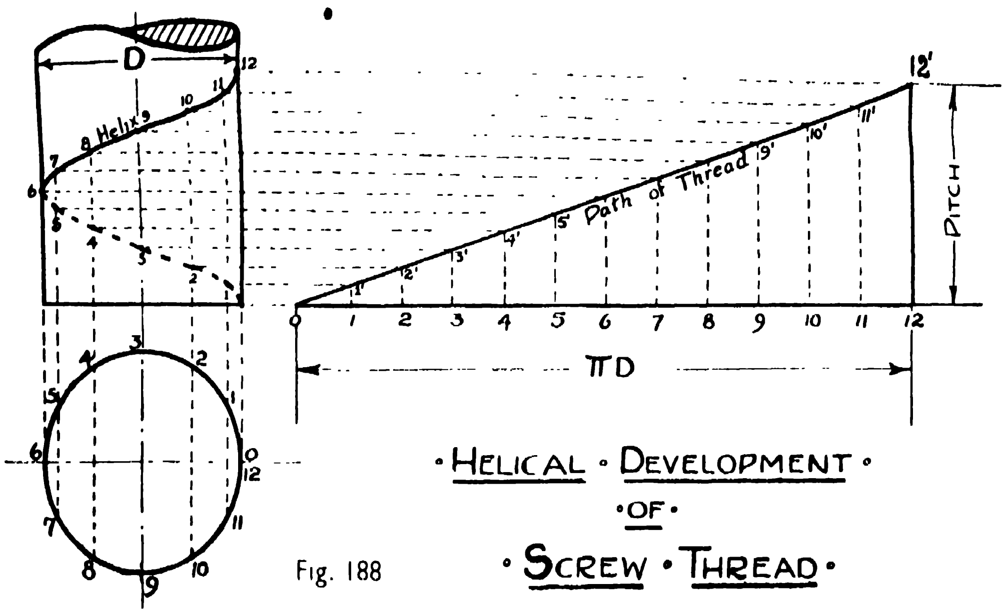


Fig. 188

To draw the helical development of a Screw Thread, Fig. 188.

Let **D** (3″) be the diameter of the cylinder on which the thread is to be cut.

The plan and elevation of this cylinder is shown.

Divide the circumference into any number of equal parts, say 12, as shown in plan

Set out a horizontal base line, **0-12**, equal to the length π**D**, that is, equal to the circumference of the cylinder, and mark the same number of equal parts (12) on it.

Erect a perpendicular, **12-12′**, equal to the pitch of the thread ($1\frac{1}{2}$″).

Join **0-12′**.

Erect perpendiculars at the points **1**, **2**, . . . **11** to meet **0-12′** in the points **1′**, **2′** . . . **11′**.

The points of intersection on the cylinder elevation, where the horizontal lines through **0′**, **1′**, **2′**, . . . **12′** meet the vertical lines from the similarly numbered points in the plan, will be points on the path of the helix.

Draw a "*smooth*" curve through these points of intersection.

THREAD FORMS. PLATE 43

Four of the common thread forms are shown on this plate, viz., **Whitworth, Sellers, Square,** and **Buttress** threads. Screws are specified according to the number of threads per linear inch of the screwed portion of the bolt shank.

The Whitworth Thread, Fig. 189. This form of vee thread is adopted as standard in engineering work throughout **Great Britain**. The special features of the Whitworth thread as well as the proportions and method of setting it out may be followed from the figure.

The Sellers Thread, Fig. 190. This form of vee thread is adopted as standard in **American** engineering practice. Here again the proportions and method of setting out may be followed from the figure.

The Square Thread, Fig. 191. This thread is not so strong as the vee thread, but it offers less frictional resistance to the nut. It is therefore used where easy working, in the transmission of motion, is required.

The Buttress Thread, Fig. 192. This thread is a combination of the square and the vee thread embodying the *easy working* of the *square thread* with the *strength* of the *vee thread.*

Examples of vee threads will be familiar to the reader, and illustrations of the square and buttress threads will be seen on the lead screw of a lathe, the screw forming part of the bench vices for woodwork and metalwork, and the screw of a "*shifting*" or adjustable spanner.

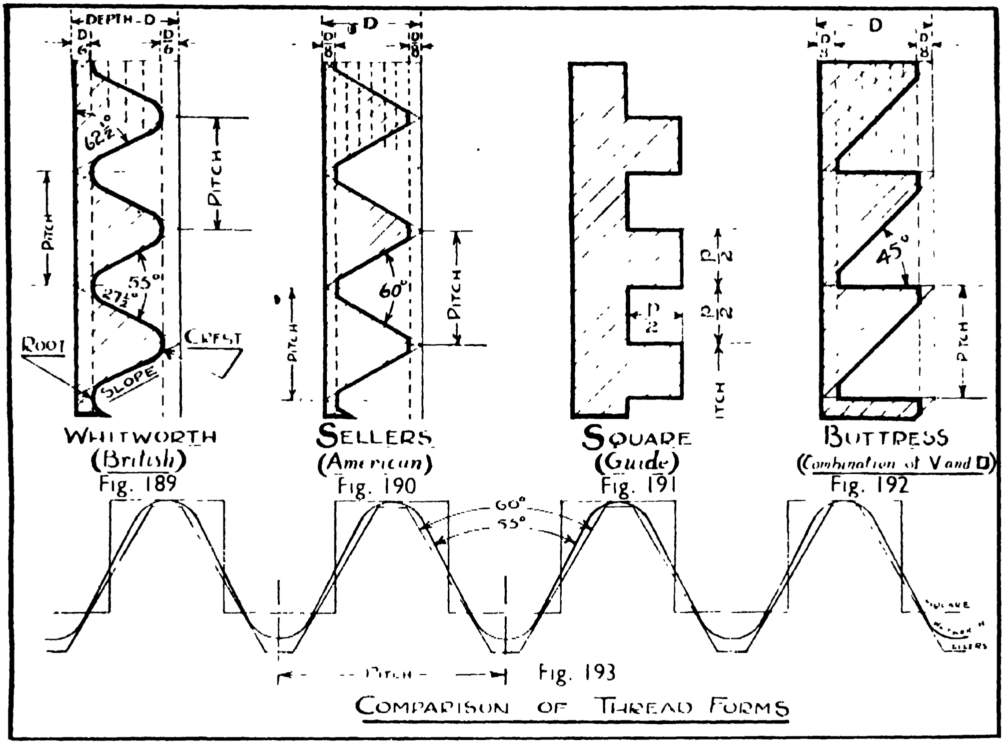
A comparison of three of the common thread forms is given in Fig. 193.

Although the actual path of a screw thread is a helix, it is never shown as such on a drawing. This would involve too much trouble for such a frequently recurring machine detail. The threads are standardised in terms of the bolt diameter; therefore it is sufficient, and much quicker, to use the conventional recommended methods shown on Plate 5 (page 27) Part I.

OTHER SCREW THREADS

Whitworth Standard Pipe Threads. This is the British standard thread for use on **gas, water** and **steam** pipes. These pipes are specified according to the nominal internal diameter or bore of the pipe.

British Standard Fine Thread. The profile of this thread is similar to the standard Whitworth (Fig. 189). There is a difference in the number of threads per inch; it is a much finer thread, i.e., it has more threads per inch than the Whitworth.



WHITWORTH (British) Fig. 189

SELLERS (American) Fig. 190

SQUARE (Guide) Fig. 191

BUTTRESS (Combination of V and ☐) Fig. 192

Fig. 193 COMPARISON OF THREAD FORMS

TABLE OF SCREW THREADS

Diam. of Screw in inches		Whitworth No. of threads per inch	Whitworth Diam. of thread at root	Sellers No. of threads per inch	Sellers Diam. of thread at root
$\frac{1}{4}$	·25	20	·1860	20	·1850
$\frac{1}{2}$	·50	12	·3933	13	·4001
$\frac{3}{4}$	·75	10	·6219	10	·6201
1	1·00	8	·8399	8	·8376
$1\frac{1}{2}$	1·50	6	1·2866	6	1·2835

EXERCISE 35

The following thread forms are to be drawn to a scale of full size.

1. Draw, to a pitch of $1\frac{1}{4}''$, three pitches of each of the following thread forms: Whitworth, Sellers, Square, and Buttress. (Figs. 189 - - 192).
2. Make a drawing showing the comparison of the above four thread forms for a pitch of 2″. (Fig. 193).

GEAR WHEELS

Gears are toothed wheels which, when in contact, are used to transmit power and motion. The gears are then said to be *in mesh*. As the correct representation of toothed gearing on a drawing is important, it will be necessary to study the principle on which toothed gearing is built up.

Fig. 194 shows two plain disc wheels, **A** and **B**, in contact, each mounted on a shaft, which is supported in a *bearing*. If **A** be made to rotate in the direction of the arrow, then **B** will rotate in the opposite direction. As the edges of the discs are smooth, motion is given to **B** purely by the friction existing between **A** and **B** at their surfaces of contact. As **A** and **B** are shown to be of the same diameter, it is obvious that if **A** is rotated through one complete revolution **B** will also make one revolution.

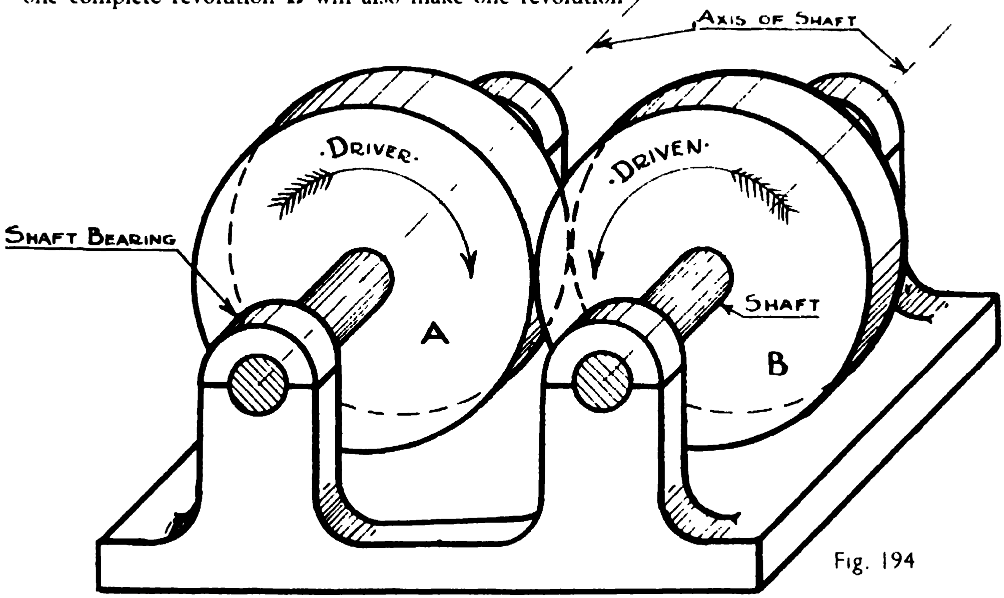


Fig. 194

Fig. 195 shows two wheels, **C** and **D**, of different diameters. The *smaller one* is called a *pinion* and the *larger one*, a *spur wheel*. The relative **speed** of rotation of the wheels **C** and **D** is known as the **velocity ratio** between them. The velocity ratio may be obtained as follows:

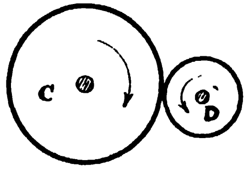
Let wheel **D** have **t** teeth and let its speed be **n** r.p.m.

Let wheel **C** have **T** teeth and let its speed be **N** r.p.m.

then $\frac{\mathbf{n}}{\mathbf{N}} = \frac{\mathbf{T}}{\mathbf{t}}$. If **D** be the driver, $\mathbf{N} = \frac{\mathbf{n} \times \mathbf{t}}{\mathbf{T}}$.

Assume **D** makes **100** r.p.m., **t** = **20** and **T** = **40**.

then **C** will make $\frac{\mathbf{100} \times \mathbf{20}}{\mathbf{40}} = \mathbf{50}$ r.p.m.



SPUR WHEEL PINION.
Fig. 195

Only small powers can be transmitted by a *friction type* of drive. As soon as the driven wheel offers a resistance in excess of the friction existing between the wheels at their surfaces of contact then *slip* will take place and an uneven transmission of power will result. The pupil should try for himself the simple experiment of comparing the friction drive between two pennies with that between two half-crowns. The *milled* edges on the latter coins prevent *slip*. Similarly and to prevent *slip*, gear wheels have teeth cut in them so that accurate transmission of motion may take place. The drive then becomes a *positive* one. It is not sufficient to cut grooves in the wheels so that the teeth on one wheel may enter grooves in the other. The shafts themselves must be brought nearer together in order that the wheels may "*mesh*". Fig. 196 shows the method of getting over this difficulty by cutting half the depth of the grooves in the wheel and adding *tips* to make up the total depth of the tooth. This is illustrated by the black portions on the teeth. The original diameter of the disc wheel is shown on the left side of wheel **A**. The new diameter, in order that teeth may be formed on the wheel while maintaining the correct velocity ratio, is shown to the right of wheel **B**. This new diameter is called the ***blank diameter*** of the wheel.

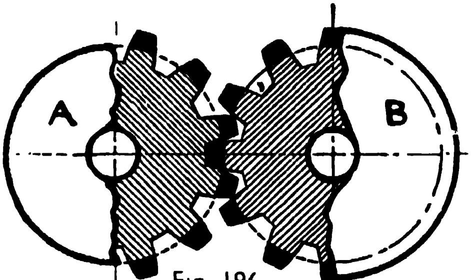


Fig. 196

Wheels having teeth cut in them, parallel to the axis of the wheel, are called **spur wheels.** They can only be used to link up *parallel* shafts. Two such wheels in contact are referred to as a *pair of wheels.*

Use of the Idler, Fig. 197. A pair of ordinary spur wheels in mesh will revolve in opposite directions. The only effect of the idle wheel **F** is to make the driven wheel **G** rotate in the same direction as the driver **E**. There is no change in the velocity ratio of the wheels **E** and **G**.

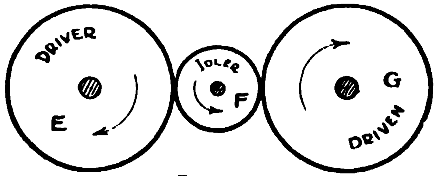


Fig. 197

To prove this, let **E** have say 30 teeth, **F** have 15 teeth, and **G** have 30 teeth (the same number as **E**).

Wheel **F** makes $\frac{30}{15} = 2$ revs. for every revolution of **E**.

Now **F** becomes driver for wheel **G**.

Wheel **G** makes $\frac{15}{30} = \frac{1}{2}$ rev. for every revolution of **F**, i.e., **G** makes 1 rev. for every 2 revs. of **F** $\therefore$ **E** and **G** run at the same speed and in the same direction.

Train of Wheels, Fig. 198. When a large velocity ratio is required this cannot be obtained by a simple pinion and wheel drive alone, as the wheel would become inconveniently large. A train of wheels is used for this purpose. Fig. 198 shows the diagrammatic plan and elevation of such an arrangement. There are four wheels on three shafts. If **A** be the driver (the wheel which sets the train in motion) then **A** drives **B**, and as **C** is mounted on the same shaft as **B**, **C** will make the same number of revolutions as **B**. **C** ultimately drives **D**. For purposes of calculation let the numbers on Fig. 198 be the number of teeth in each wheel (**A**-**90T**, **B**-**15T**, **C**-**120T**, **D**-**20T**).

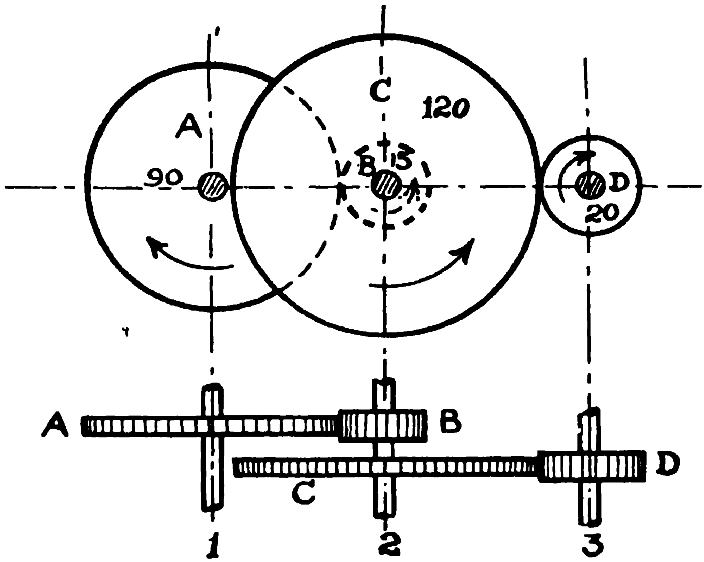


Fig. 198

TRAIN OF WHEELS

Let No. 1 shaft make say 40 revolutions per minute (r.p.m.).

Revs. of No. 2 shaft $40 \times \frac{90}{15} = 240$ r.p.m.

Revs. of No. 3 shaft $240 \times \frac{120}{20} = 1440$ r.p.m.

This train has a velocity ratio of $\frac{1440}{40} = \frac{36}{1}$.

$$\text{Velocity Ratio} = \frac{\text{Product of number of teeth in drivers}}{\text{Product of number of teeth in driven wheels}}$$

$$= \frac{90 \times 120}{15 \times 20} = \frac{36}{1}.$$

GEAR WHEELS — PLATE 44

Spur wheels are more generally used than any other type of gear wheel. The diameter of a gear wheel is always understood to be that of its "*pitch circle*." The teeth are cut according to (1) **Circular Pitch** (**C.P.**) or (2) **Diametral Pitch** (**D.P.**); but cutting according to **C.P.** has now been more or less superseded by the more convenient method of **D.P.**

FORMULAE FOR DIAMETRAL PITCH—TWO GEAR WHEELS

T,t—Teeth: Number of teeth in the wheels.

P.D.—Pitch Circle Diameter: The diameter of an imaginary circle, called the *pitch circle*, which makes rolling contact with a similar circle on another wheel.

D.P.—Diametral Pitch: The number of teeth per inch of the pitch circle diameter.

B.D.—Blank Diameter: The diameter of the cylinder before teeth have been cut round its circumference.

R.D.—Root Diameter: The diameter of the circle touching the roots of the teeth.

T.T.—Tooth Thickness: The thickness of the tooth as measured at the pitch circle.

B.C.—Base Circle Diameter. This is equal to **·96PD.**

Crs.—Distance between centres of the two wheels is equal to $\dfrac{T + t}{2 \cdot DP}$.

Example: **Large Wheel 36 teeth of 6 D.P. (Fig. 199).**

Pitch Circle P.C. $\dfrac{T}{DP} = \dfrac{36}{6} = 6''$ diam. **Blank Diam. B.D.** $\dfrac{T+2}{6} = \dfrac{38}{6} = 6{\cdot}33''$

Root Circle R.D. $\dfrac{T-2}{6} = \dfrac{34}{6} = 5{\cdot}66''$ diam. **Tooth Thickness T.T.** $\dfrac{1{\cdot}57}{6} = {\cdot}26''$

Small Wheel—Similar calculations.

EXERCISE 36 — Use 22″ × 15″ paper — PLATE 44

(Study Note on opposite page)

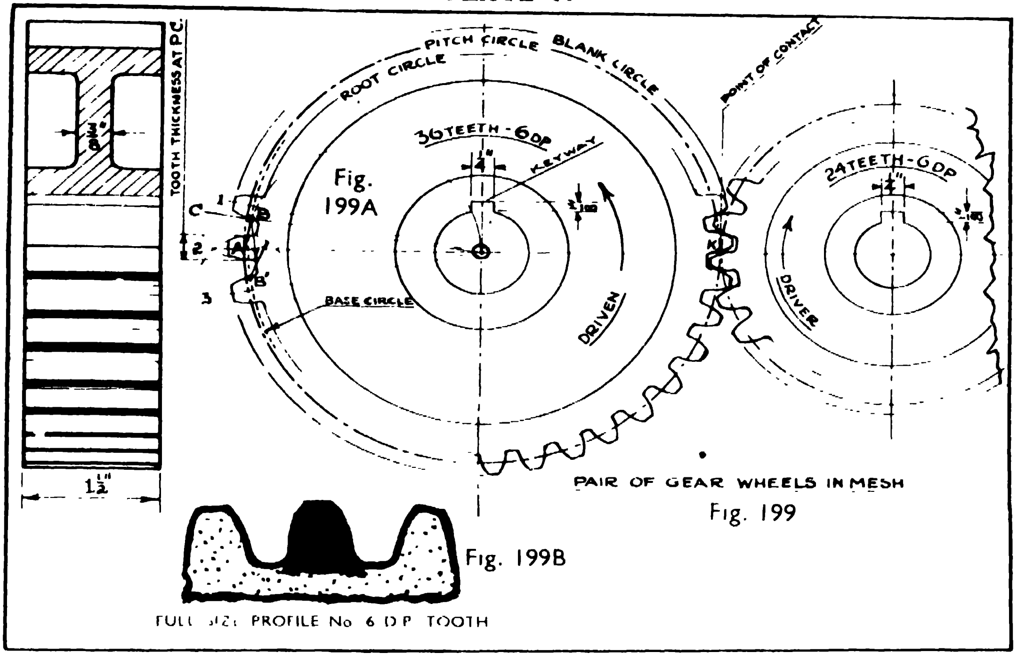
Fig. 199 shows a pair of gear wheels in mesh.

Draw, to a scale of full size, the wheel teeth in contact and project a half sectional end view of the large wheel.

Fig. 199B shows the **actual** profile for the tooth of **6DP**. Make an enlarged view of the three teeth (1, 2, 3), twice full size.

Calculate the diameters of the blank, pitch and root circles for a wheel **46 teeth 5 DP**. What will be the thickness of the tooth?

PLATE 44



PAIR OF GEAR WHEELS IN MESH

Fig. 199

Fig. 199B

FULL SIZE PROFILE No 6 D P TOOTH

Note : The profile of the tooth curve is an involute , but an approximation, using circular arcs, can be used (Fig. 199A).

Set out the radial lines of three teeth as **0-1**, **0-2**, **0-3** at distances of $\frac{\pi \cdot 6''}{36} = \cdot 52''$ (or alternatively by arcs subtending $\frac{360}{36}$ 10 at the centre).

Set out the thickness of the tooth $\frac{1 \cdot 57}{\mathbf{DP}} = \frac{1 \cdot 57}{6} = \cdot 26''$ on the pitch circle.

Point **B** lies on No. 1 tooth curve at the point of intersection of semi-circle **OBA** and the radial line **OC** through the tooth thickness at the base circle.

AB′ (No. 3 tooth) **AB.**

With **B** and **B′** as centres, draw the circular arcs of No. 2 tooth finishing with a small fillet curve to join up with the tooth root.

Complete teeth Nos. 1 and 3.

Other teeth on the wheel can be drawn in by the careful use of tracing paper, after drawing in the radial centre lines.

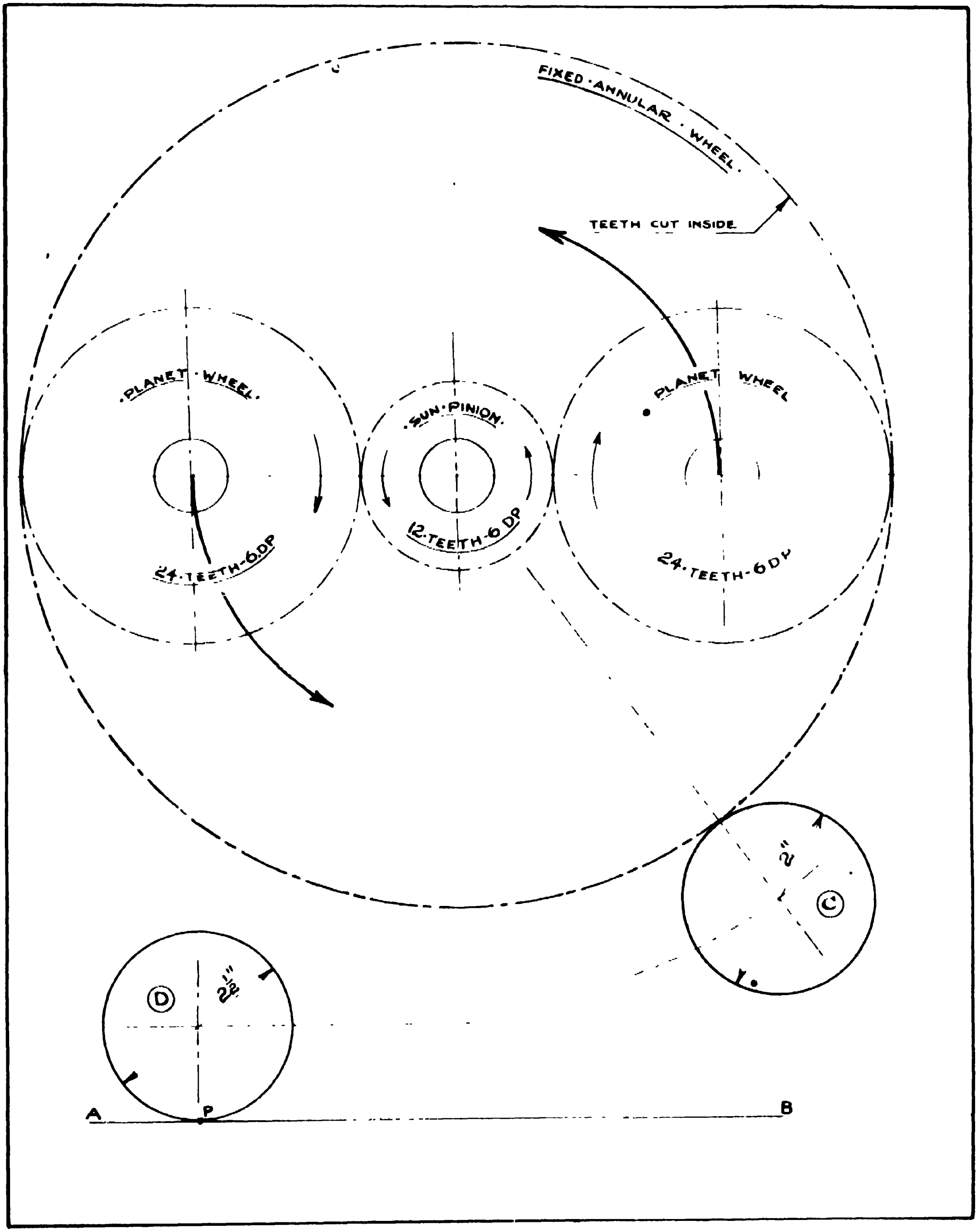
EXERCISE 37 — Use 22″ × 15″ paper — PLATE 45

An arrangement of gear transmission known as " *Sun and Planet* " motion is shown. The sun pinion drives the two planet wheels round in a fixed annular wheel thus giving a reduction gearing. The two planet wheels are rigidly connected together and free to turn the sun pinion.

(a) Draw the system, to a scale of full size, and plot the locus of a point on a planet wheel as it makes one complete revolution within the annular wheel circle.

(b) Plot the locus of a point on circle **C** as it makes one revolution on the outside of the annular wheel circle.

(c) Cut out a circle **D**, $2\frac{1}{2}''$ diameter, from a piece of thin cardboard and mark a point **P** on the circumference. Place **P** on the horizontal line **A-B** and roll the circle carefully along the line, marking the position of **P** at frequent intervals until it arrives on **A-B** again. Draw a smooth curve through the various points.


FIXED · ANNULAR · WHEEL ·
TEETH CUT INSIDE
· PLANET · WHEEL ·
24 · TEETH · 6 DP
· SUN · PINION ·
12 · TEETH · 6 DP
· PLANET WHEEL
24 · TEETH · 6 DP
2"
C
D
$2\frac{1}{2}$"
A
P
B

CHAPTER 6

CYLINDER — SPHERE — CONE — CONIC SECTIONS (CIRCLE, TRIANGLE, ELLIPSE, PARABOLA, HYPERBOLA)

The cylinder, the cone and the sphere have been referred to as the "*Round Bodies.*"

CYLINDER

The **Cylinder** is a solid formed by the revolution of a rectangle about one of its sides as axis.

To draw the elevation, plan, end view and sectional end view of a cylinder, $2\frac{1}{2}''$ diameter $3\frac{1}{2}''$ long, with its axis parallel to VP and inclined at 30 to HP, Fig. 200.

The elevation will be the rectangle ($3'' \times 2''$) **ABDC**.

Draw the trace of any verticle section **S-N**.

On **AB** describe a semi-circle and mark any points **1 - - - 5** on **AB** with **3** on the centre line.

Draw **1′-1, 2′-2 - - - - 5′-5,** and produce parallel to **AC,** to meet **CD.**

As the axis is parallel to **VP** the plan will be $2\frac{1}{2}''$ broad.

Project lines from **A, 1, 2, - - - 5, B** (elevation) to the plan and set off the corresponding ordinates **1-1′, 2-2′, - - - 5-5′** on each side of the centre line **AB** (plan, giving the points **1′, 2′ - - - - 5′** in that view. Draw a smooth curve through these points giving the ellipse (**AB** minor axis and **3′-3′** major axis) and observe that a portion of the ellipse will be shown as hidden.

The ellipse representing the other end of the cylinder in plan is obtained in the same way and may be followed from the figure.

The full end view and the sectional end view are obtained by similar methods and note that the ordinates from **S, 6, 7 - - - 10, N** in the sectional end view (**6-1′, 7-2′, - - - 10-5′**) will be the same as **1-1′, 2-2′ - - - - 5-5′** in the plan.

Fig. 201 shows the plan of the same cylinder ($3'' \times 2''$ diameter) with its axis inclined at 45 to V.P. and parallel to H.P. It is cut by a plane S-N which is parallel to VP.

Draw the given plan and sectional elevation.

Complete the full end view.

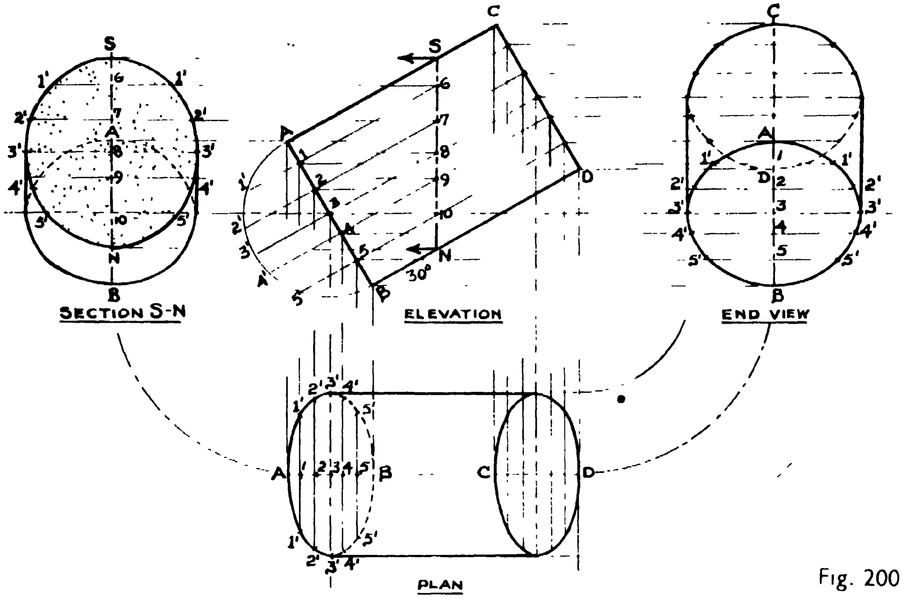


Fig. 200

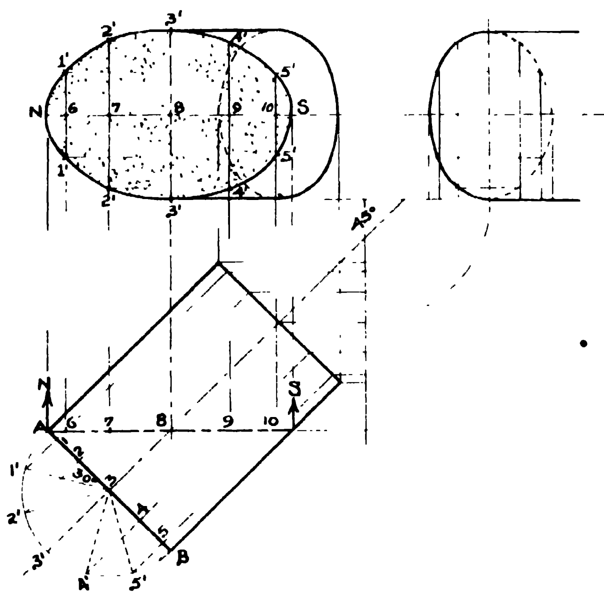


Fig 201

EXERCISE 38 — Use 22″ × 15″ paper — PLATE 47

Fig. 202 shows the plan and elevation of part of a cylinder pierced centrally by a hole which is 1″ square.

Draw, to a scale of full size, the given views and add in the positions shown :—

(a) The complete true shape of the sloping surface showing the hole.

(b) The full end view.

(c) The sectional end view on the cutting plane **S-N.**

Fig. 203 shows a 3″ diameter pipe passing through a pitched roof.

Draw, to a scale of full size, the given view and add in the positions shown :—

(a) The complete end view.

(b) The true shape of the hole in the roof.

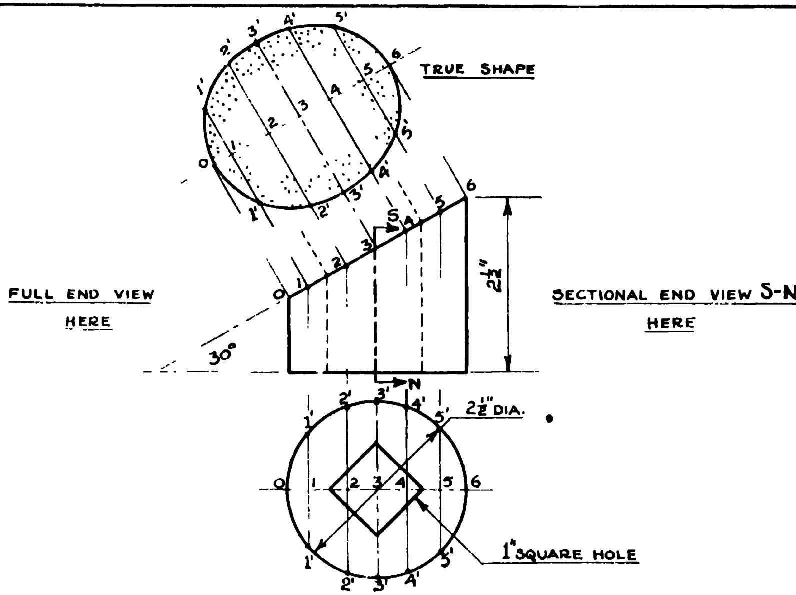


Fig. 202

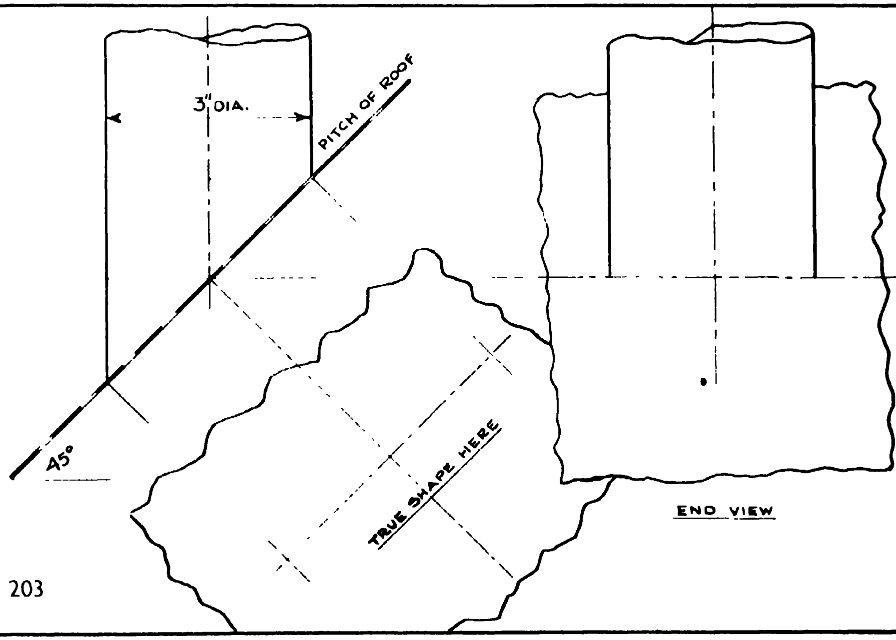


Fig. 203

EXERCISE 39 — Use 22″ · 15″ paper — **PLATE 48**

Fig. 204 shows the part of a rectangular tank with sloping sides. There is a horizontal inlet pipe($1\frac{1}{4}$″ diameter) at the end and an outlet pipe ($1\frac{1}{2}$″ diameter) from the bottom. The centre lines of the pipes are in the same vertical plane.

Draw, to a scale of full size :—

(a) The given elevation.

(b) The complete plan and end views.

Fig. 205 shows the intersection of four round bars.

Draw, to a scale of full size, and in the positions shown :—

(a) The given elevation.

(b) The full end view.

(c) The sectional plan on **A-A.**

(d) The sectional end view on **B-B.**

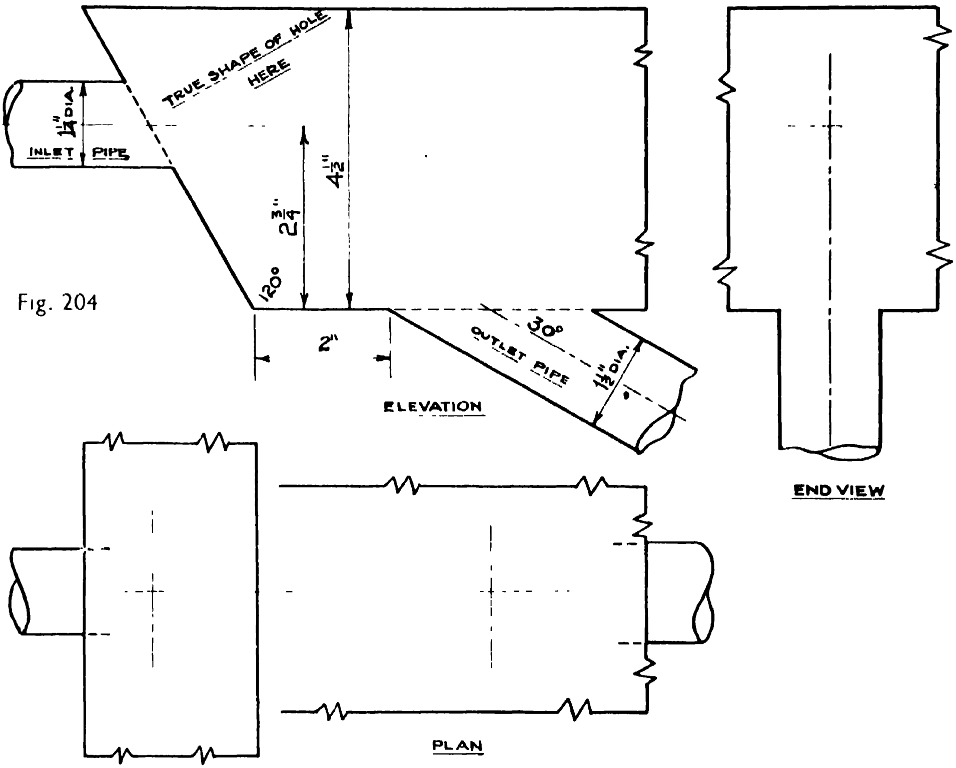


Fig. 204

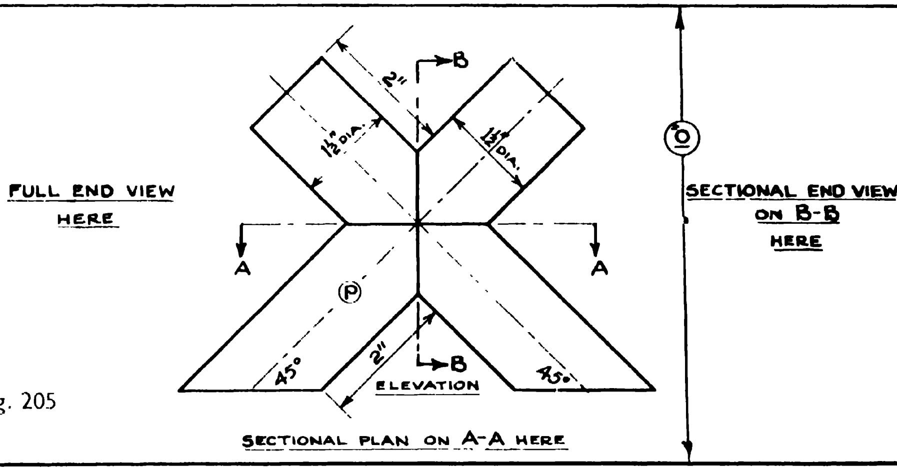


Fig. 205

THE SPHERE

The **Sphere** is a solid formed by the revolution of a semi-circle about its diameter as axis.

To draw the plan and elevation of a $2\frac{3}{4}''$ sphere, standing in H.P., when cut by any plane parallel to V.P. (Fig. 206).

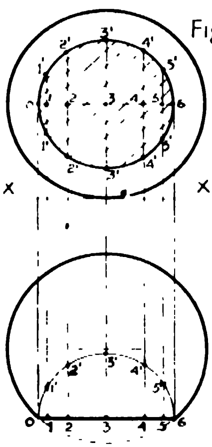


Fig. 206

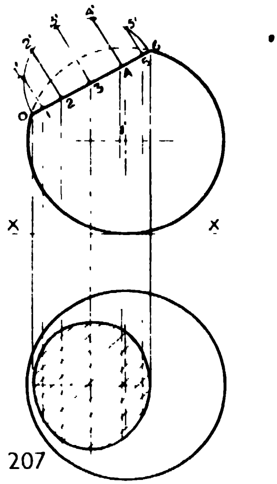


Fig. 207

The plan will be a circle $2\frac{3}{4}''$ diameter and the cutting plane is represented by a straight line, e.g., **0 - - - 6**.

(1) Select any number of points on this line, say **1, 2 - - - 5.** Describe a semi-circle on **0 - - - 6.**

(2) From **1, 2 - - - 5** draw perpendiculars to meet the semi-circle in **1′, 2′ - - - 5′.**

The horizontal and vertical centre lines in the elevation are now drawn and a circle, $2\frac{3}{4}''$ in diameter, is described touching the **XX** line.

(3) Project the points **0, 1, 2 - - - 6** from the plan to the centre line in the elevation.

On each side of **0-6**, in the elevation, set off the respective ordinates **1-1′, 2-2′, - - - 5-5′**, when it will be found that the curved line joining the points so obtained will be the circumference of a circle, whose diameter is equal to the length of the cutting plane, **0 - - - 6,** seen in plan.

To draw the plan and elevation of a $2\frac{3}{4}''$ sphere, standing on H.P., when cut by an oblique plane, 0-6 (Fig. 207).

The projected plan of the section will be an ellipse and the method of obtaining it may be followed easily from the figure and the previous constructions.

To draw the plan and elevation of two spheres, 3″ and $1\frac{1}{2}''$ diameter, respectively, both standing in H.P. and in contact. The line joining their centres is parallel to V.P. (Fig. 208).

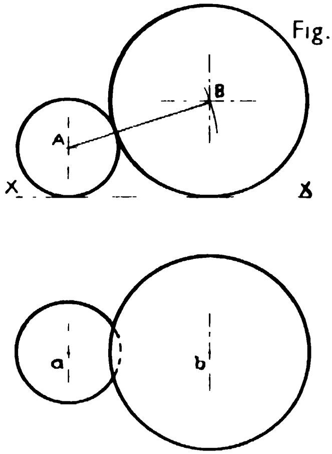


Fig. 208

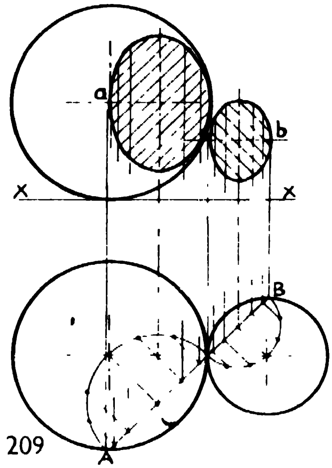


Fig. 209

With centre **A** radius $\frac{3}{4}''$, draw a circle touching the **XX** line and representing the elevation of the smaller sphere.

Draw a centre line, parallel to **XX** line, at a distance of $1\frac{1}{2}''$ from it (radius of larger sphere).

With centre **A**, radius $2\frac{1}{4}''$ (*the sum of the radii of the two spheres*), cut this centre line in **B**.

With centre **B**, radius $1\frac{1}{2}''$, draw a circle.

This circle, touching the **XX** line (and also the smaller circle) will represent the elevation of the larger sphere.

As the line, joining the centres of the spheres, is parallel to **V.P.**, draw a centre line parallel to **XX** line in the plan.

On this line drop the vertical projectors, through **A** and **B**, giving **a, b**.

With centres **a, b**, and radii $\frac{3}{4}''$ and $1\frac{1}{2}''$ respectively, draw the two circles representing the plan of the two spheres and mark the point of contact with a heavy dot.

Fig. 209 shows the plan of two spheres, $2\frac{3}{4}''$ and $1\frac{1}{2}''$ diameter, which *appear* to be in contact. The spheres are resting on H.P. and the line joining their centres is parallel to V.P. Draw this plan and insert a cutting plane **AB**, inclined at 45 to V.P. and passing through the "*apparent point of contact*" in the plan view.

Project a sectional elevation of this arrangement as shown on the figure.

Ascertain the distance, in inches, that the centres of the spheres are apart.

EXERCISE 40 — Use 22″ × 15″ paper — PLATE 49

1. **Fig. 210** shows the plan of two spheres in contact. The line joining their centres is parallel to H.P. and inclined at 60° to V.P. Draw this plan and project an elevation.

   Superimpose a sectional elevation when the spheres are cut by a vertical plane passing through their centres.

2. **Fig. 211** shows the elevation of three spheres. The lines joining their centres lie in the same vertical plane and this plane is parallel to V.P. Draw the elevation and project a plan.

3. **Fig. 212** shows the elevation of a square bar passing through a sphere. The sphere has been "flattened," where the bar enters and leaves, by an amount *just sufficient* to provide a plane surface for the bar at these places, i.e., the diameter of the "flattened" portion of the sphere is equal to diagonal of the square forming the bar.

   Draw the following views :—

   (a) The given elevation and project a plan.

   (b) Another elevation and sectional plan, when cut by a plane **AB** parallel to H.P. and passing through the centre of the sphere.

   (c) A further elevation and sectional plan, when cut be a plane **CD** inclined at 45° to H.P. and passing through the centre of the sphere.

Fig. 213 shows the plan of three spheres, each $2\frac{3}{4}$″ diam., standing on the H.P. and surmounted symmetrically by a smaller sphere, of 2″ diam. The four spheres are in contact with one another.

(a) Draw the given plan and project an elevation. State the height of the centre of the 2″ sphere above the H.P.

(b) Draw an auxiliary sectional elevation on **A-B** passing through the centre of one large sphere and the centre of the small sphere.

(c) Mark, with heavy dots on the plan and elevation, the points of contact between the small sphere and the two front large spheres. State the height of these points of contact above the H.P.

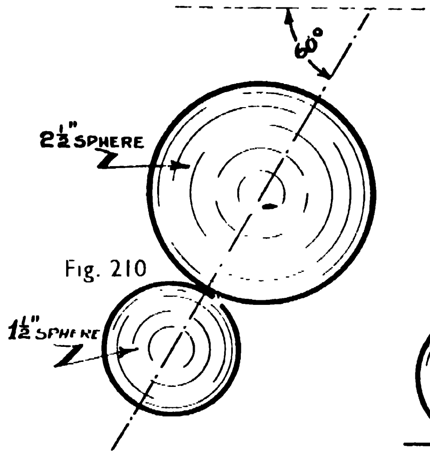


Fig. 210

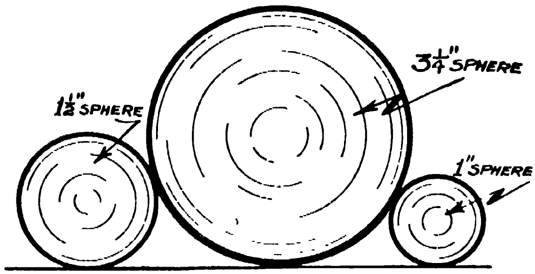


Fig. 211

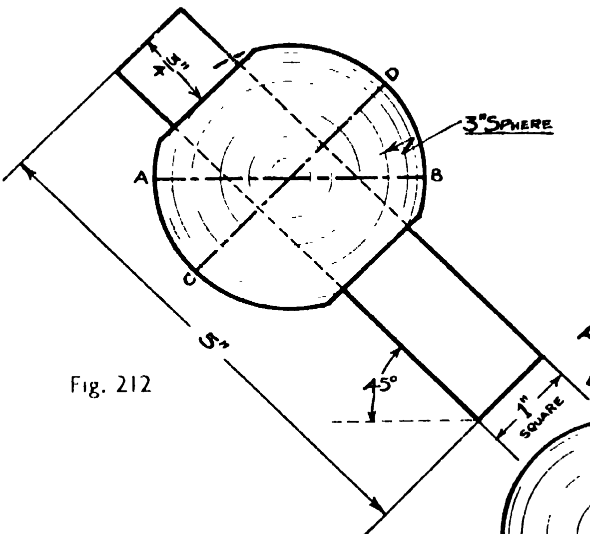


Fig. 212

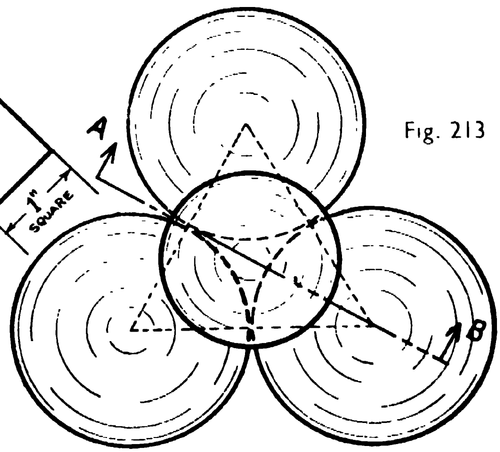


Fig. 213

THE CONE

The **Cone** is a solid formed by the revolution of a right-angled triangle about one of its sides as axis.

To draw the elevation, plan, end view and sectional end view of a cone, base 3″ diameter and $3\frac{1}{2}$″ vertical height. The base is inclined at 45° to HP and the axis is parallel to VP (Fig. 214).

The elevation will be an isosceles triangle, 3″ base, **0 - - - 6**, inclined at 45° to **HP** and vertical height $3\frac{1}{2}$″.

Describe a semi-circle on **0 - - - 6** and divide it into 6 equal parts in **1′, 2′ - - 5.**

Draw **1′-1, 2′-2 - - - 5′-5** perpendicular to **0-6** and meeting it in **1, 2 - - - 5.**

Project lines from **0, 1, 2 - - - 6** (elevation) to the plan and set of corresponding ordinates **1′-1, 2′-2 - - - 5′-5** on each side of the centre line **0-6** (plan) giving the points 1′, **2′ - - - 5′** in that view. Draw a smooth curve through these points and observe that half the ellipse will be shown as hidden.

Project the apex from the elevation to the plan and complete the plan by drawing lines from the apex tangential to the ellipse.

The full end view and the sectional view are obtained by similar methods as indicated in these views.

Note : These constructions are similar to those for the ends of a cylinder (Plate 46) since any section of a cone taken parallel to the base is a circle.

EXERCISE 41 — PLATE 50

Fig. 215 shows the elevation and plan of a cone, 3″ diameter base and 4″ slant height, resting on **HP**. Two rectangular blocks, each $1\frac{1}{2}$″ × $\frac{3}{4}$″ × 2″ high, are placed, as shown, to prevent the cone from rolling.

Draw, to a scale of full size, the given views and add :—

(a) The full end view.

(b) Superimpose on the plan view the section obtained by the cutting plane **S-N.**

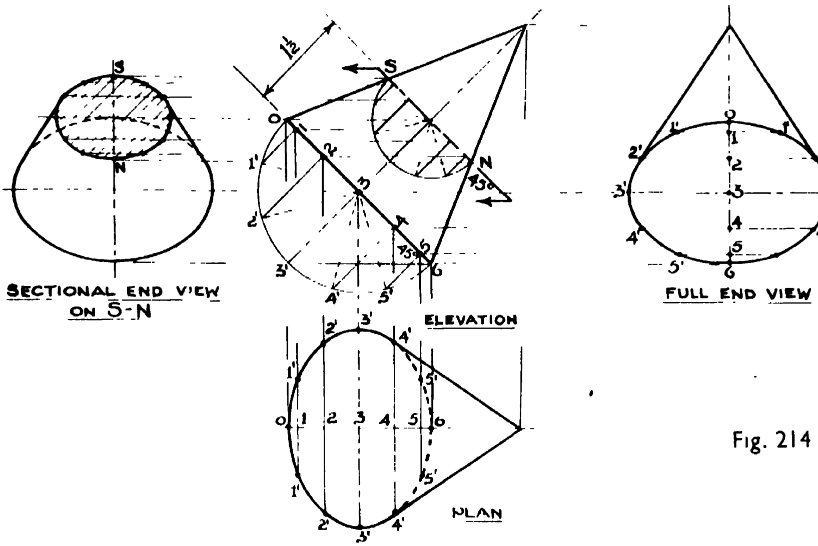


Fig. 214

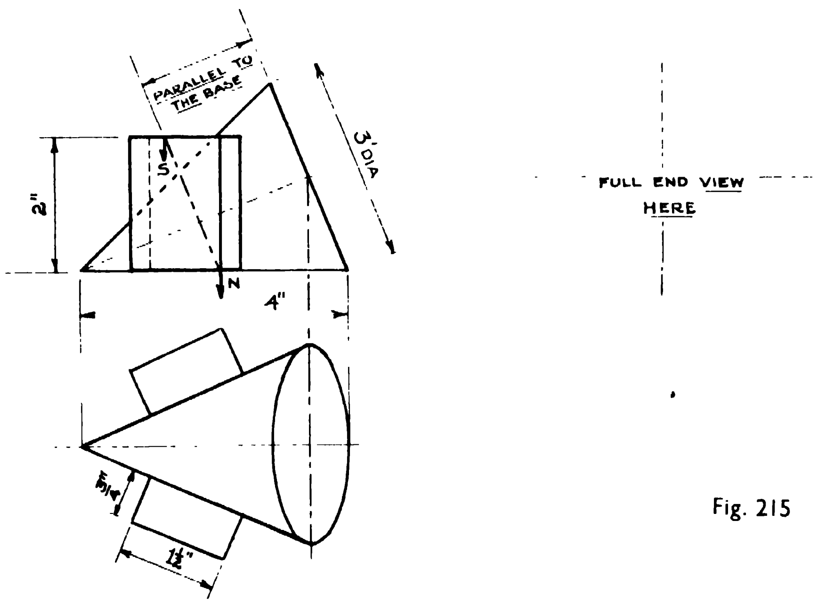


Fig. 215

CONIC SECTIONS PLATE 51

Fig. 216A shows the sketch of a right circular cone and **A** is the angle between the axis and the slant element. A conic section is the curve obtained when such a cone is cut by a plane in different ways. There are **FIVE CONIC SECTIONS (Fig. 216)** :—

1. **Circle.** The curve obtained when the cutting plane **SN** is parallel to the base. The diameter of the circle is at right angles to the axis of the cone (**Fig. 217**).

2. **Triangle.** An isosceles triangle is obtained when the vertical cutting plane **SN** includes the apex. The vertical height of the triangle is at right angles to base of the cone (**Fig. 218**).

3. **Ellipse.** The curve obtained when the plane **SN** cuts both sides of the cone but not the base. Angle B is greater than the angle between the cone axis and the elements (**Fig. 219**).

4. **Parabola.** The curve obtained when the plane **SN** is parallel to the slant side of the cone. Angle C is equal to the angle between the cone axis and the elements (**Fig. 220**).

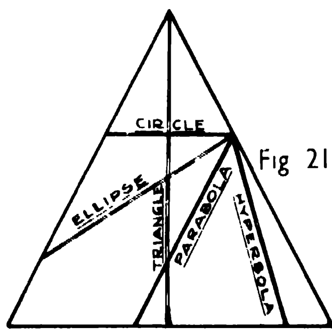
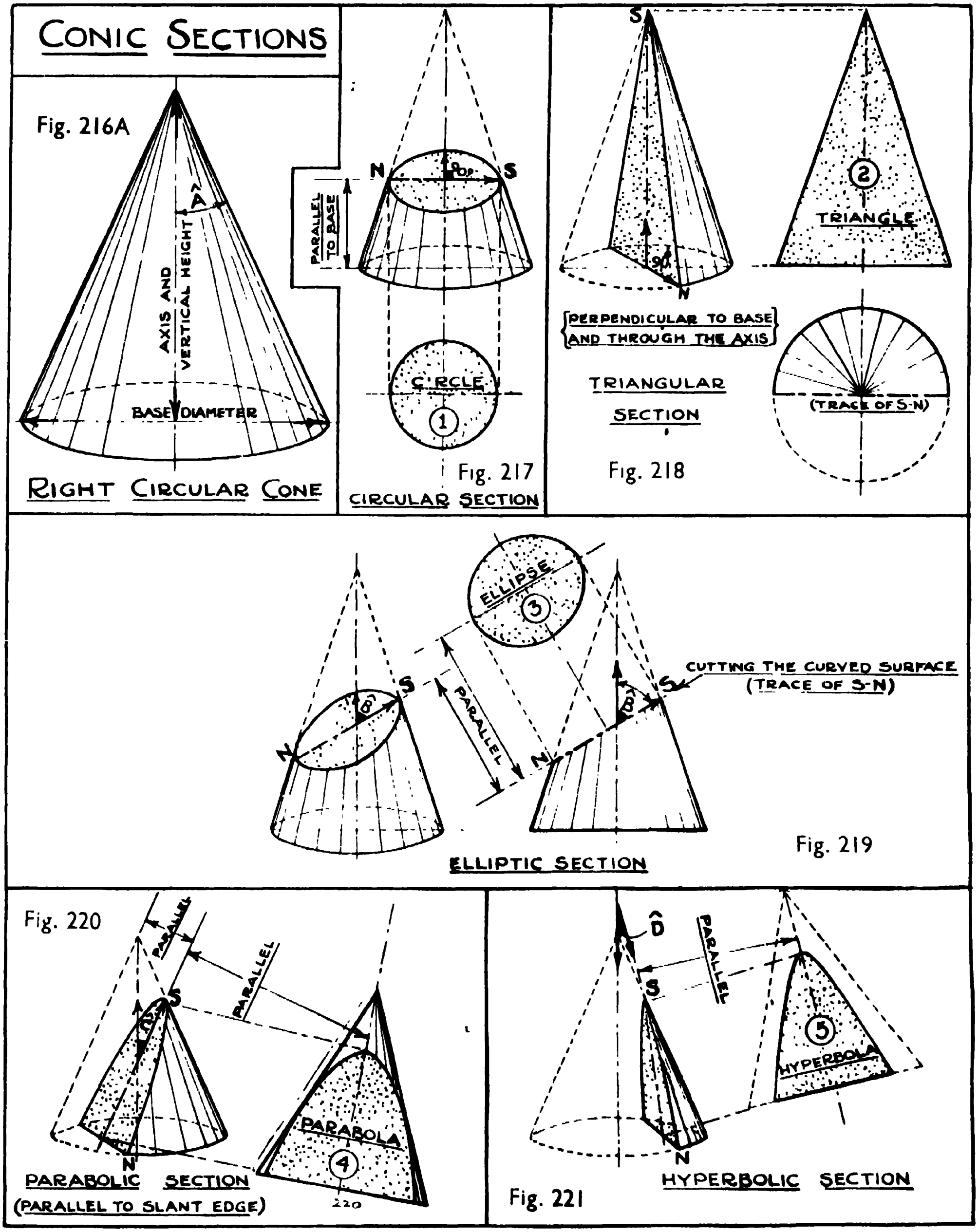


Fig 216

RIGHT CIRCULAR CONE

5. **Hyperbola.** The curve obtained when the plane **SN** makes an angle with the slant side which is less than that of the parabola. Angle D is smaller than the angle between the cone axis and the elements ; the base angle is greater than that between the slant side and the base (**Fig. 221**).


CONIC SECTIONS
Fig. 216A
A
AXIS AND VERTICAL HEIGHT
BASE DIAMETER
RIGHT CIRCULAR CONE
N
S
90°
PARALLEL TO BASE
CIRCLE
1
Fig. 217
CIRCULAR SECTION
S
2
TRIANGLE
90°
N
PERPENDICULAR TO BASE AND THROUGH THE AXIS
TRIANGULAR SECTION
(TRACE OF S-N)
Fig. 218
ELLIPSE
3
S
B
N
PARALLEL
CUTTING THE CURVED SURFACE (TRACE OF S-N)
Fig. 219
ELLIPTIC SECTION
Fig. 220
PARALLEL
PARALLEL
S
N
PARABOLA
4
PARABOLIC SECTION
(PARALLEL TO SLANT EDGE)
D
PARALLEL
S
5
HYPERBOLA
N
HYPERBOLIC SECTION
Fig. 221

METHOD OF DRAWING THE CONIC SECTIONS — PLATE 52

EXERCISE 43 — Use 22″ × 15″ paper

Figs. 222 and 223 show the elevation and plan respectively of a right circular cone, base diam. $3\frac{3}{4}$″ and vertical height $4\frac{1}{2}$″.

Vertical Section (Fig. 224). Any section which passes through the apex of the cone, and is perpendicular to the base, has the shape of an **isosceles triangle.** The base of the triangle is equal to the base diameter of the cone and the vertical height is equal to that of the cone.

Circular Section (Fig. 225). Any section which is parallel to the base (*and therefore at right angles to the axis of the cone*) is **circular in shape.** The diameter of the circle will be equal to the trace of the section plane, e.g. **OA** (Fig. 222).

Elliptical Section (Fig. 226). Any section which cuts the curved surface of the cone has the shape of an **ellipse,** e.g. **OG** (Fig. 222). Mark off any number of points, say five, on **OG** (Fig. 222), preferably with one (**3**) at the mid-point of the line, as this will locate the minor axis of the ellipse.

Through these points, **0.1.2.- - - 5.G**, draw chain lines parallel to the base and meeting the slant edge of the cone in **A.B. - - - F.G.**

Draw the centre line $\mathbf{G^2O^2}$ (Fig. 226) parallel to **OG.**

At the point **4** draw a projector perpendicular to **OG** and intersecting $\mathbf{G^2O^2}$ (Fig. 226).

The horizontal line through **4** meets the slant edge of the cone in **E** (this section will be a circle with radius **RE**).

With P^1 (plan) as centre and radius **RE** describe a circle commencing at $\mathbf{E^1}$.

Drop a perpendicular projector from **4** cutting this circle in $\mathbf{4^1}$ and $\mathbf{4^1}$ giving two points on the curve of the **elliptical section** in plan.

Set off **half** the length $\mathbf{4^1}$-$\mathbf{4^1}$ on each side of $\mathbf{G^2O^2}$ giving two points **4** and **4** on the **ellipse** (Fig. 226).

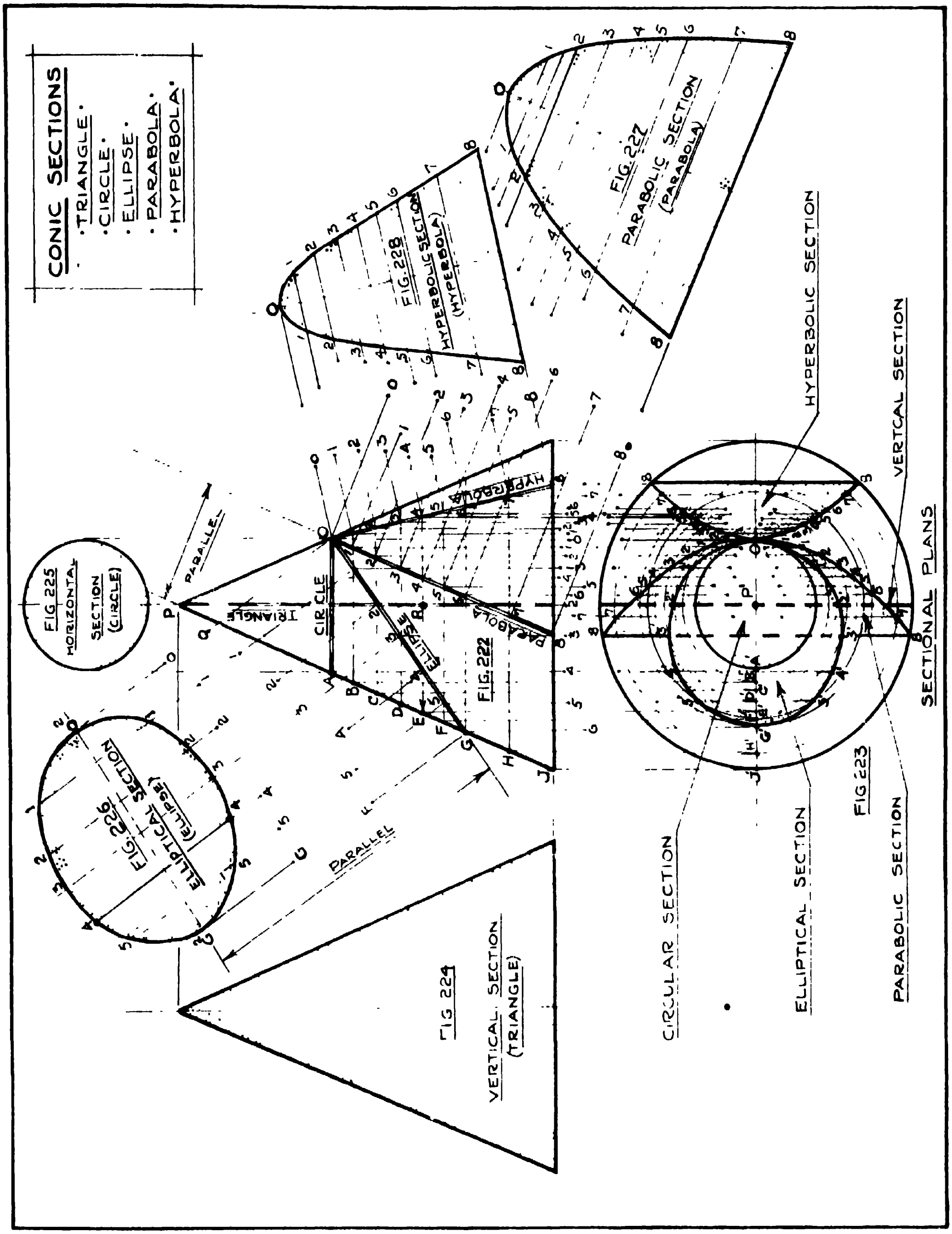
Other points for obtaining the shape of the elliptical section in plan (Fig. 223) and for the ellipse (Fig. 226) are obtained in the same manner and can be traced out on the drawings. Draw a smooth curve through these points.

Parabolic Section (Fig. 227). The constructions for the **parabolic section** in plan and for the **parabola** are carried through as described for the elliptical section, and can be traced out on the drawings.

Hyperbolic Section (Fig. 228). Again, the constructions for the **hyberbolic section** in plan and for the **hyperbola** are carried through as described for the elliptical section, and can be traced out on the drawings.

GENERAL RULE : For any point on a conic section, obtain the length of the chord from the corresponding circular section in plan, and use this to obtain two points (indicating width) on the curves.

PLATE 52


CONIC SECTIONS
· TRIANGLE ·
· CIRCLE ·
· ELLIPSE ·
· PARABOLA ·
· HYPERBOLA ·
FIG 225
HORIZONTAL
SECTION
(CIRCLE)
FIG. 226
ELLIPTICAL SECTION
(ELLIPSE)
FIG 224
VERTICAL SECTION
(TRIANGLE)
PARALLEL
FIG. 222
TRIANGLE
CIRCLE
ELLIPSE
PARABOLA
HYPERBOLA
FIG. 228
HYPERBOLIC SECTION
(HYPERBOLA)
FIG. 227
PARABOLIC SECTION
(PARABOLA)
FIG 223
SECTIONAL PLANS
CIRCULAR SECTION
ELLIPTICAL SECTION
PARABOLIC SECTION
HYPERBOLIC SECTION
VERTCAL SECTION

EXERCISE 43 — Use 22″ × 15″ paper — **PLATE 53**

Fig. 229 shows the outline of a turned ornament, built up in three parts.

Draw, to a scale of full size, and in the positions shown :

(a) The given elevation.
(b) The plan.
(c) The sectional end view on **A-A.**
(d) The true shape of the section on **B-B.**

All constructions should be very light and remain on the drawings.

Fig. 230 shows the portion of a viaduct arch and the curve is that of a cycloid.

Draw, to a scale of 1″ to 10 feet, the given view and leave in all construction lines.

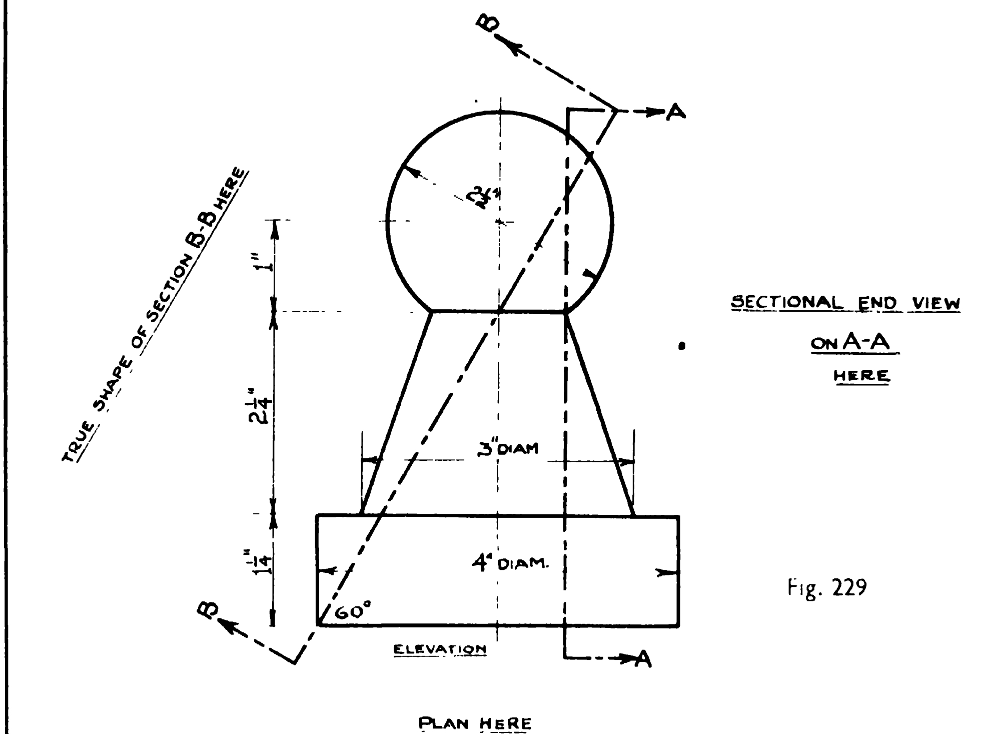


Fig. 229

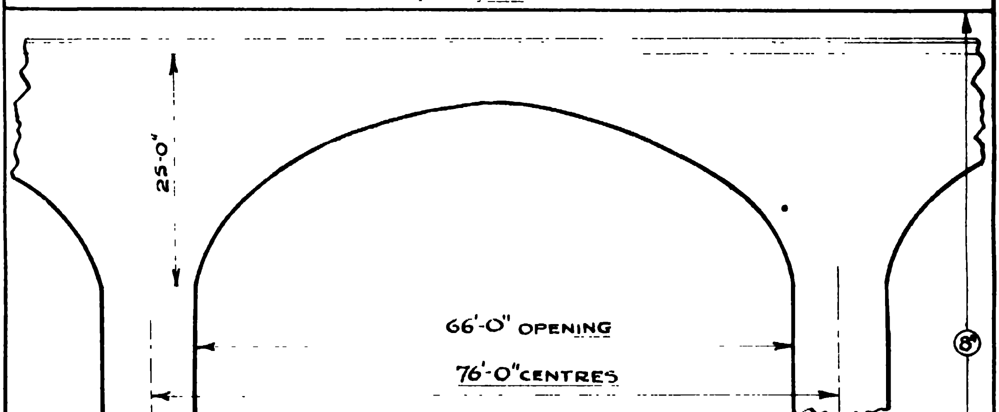


Fig. 230

CHAPTER 7

SURFACE DEVELOPMENT OF CYLINDER AND CONE — INTERSECTIONS AND CURVES OF INTERPENETRATION; CONE, CYLINDER AND SPHERE — FILLET CURVES

A very important branch of technical drawing is that which is based upon the surface developments of and curves of interpenetration between cylinders and cones. The surface of a sphere cannot be developed accurately, and such a development can only be shown, in one plane, by approximate methods.

SURFACE DEVELOPMENT OF A CYLINDER — PLATE 54

Fig. 231 shows a cylinder being rolled along a straight line. The length of the circumference is represented by **0-12**. Divide the cylinder end into any number of equal parts (say **12**) and divide the base line circumference, **0-12**, into the same number of equal parts. The development of the curved surface of the cylinder will be a rectangle, whose length is equal to **0-12** and breadth equal to the height (or length) of the cylinder.

Suppose the cylinder is cut obliquely by a plane and the back portion **Y** is removed, then the trace of the curved outline of the section, marked **0¹.1¹.2¹ - - -11¹.12¹**, can be plotted through the correspondingly numbered points on the surface development as the cylinder rolls along the base line **0-12**. From the points **0.1.2- - - 10.11** on the base of the cylinder, draw the generators **0-1¹. 1-1¹.- - -10-10¹. 11-11¹** on the surface of the cylinder and transfer these distances to their corresponding positions on the cylinder development at **0¹.1¹.2¹.- - -11¹. 12¹**. Join these points for the trace of the outline of the section as shown on the curve **0¹-12¹**. The dotted surface below the curve represents the surface development of the cut cylinder **X** and that above the curve is the surface development of that portion of the cylinder which has been removed **Y**

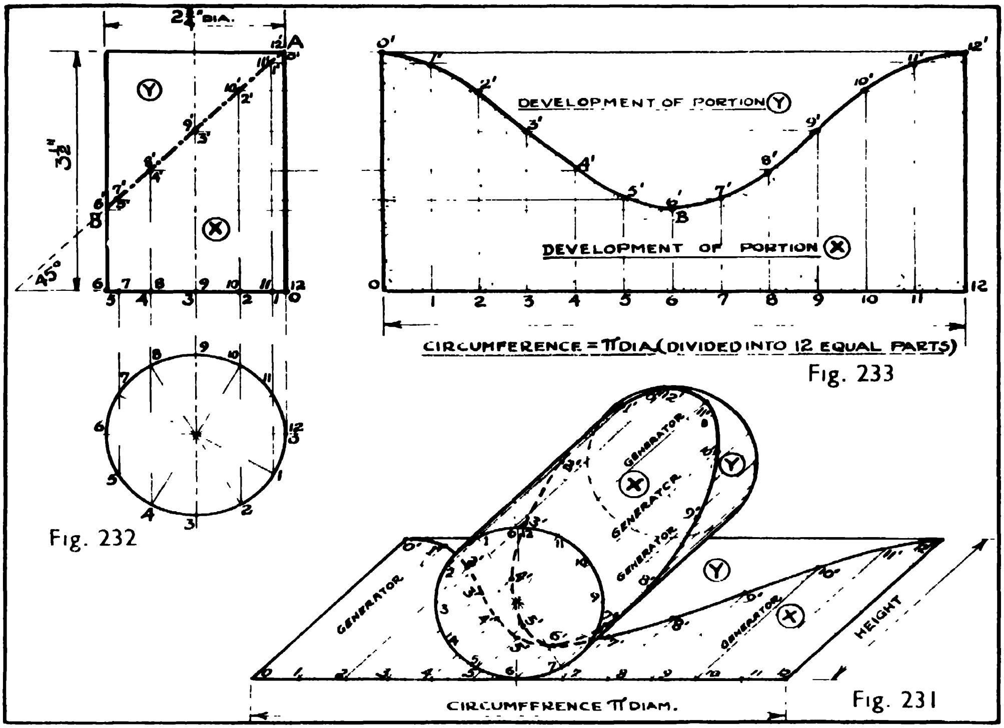


Fig. 232

Fig. 233

Fig. 231

To draw the surface development of a cylinder and of the portion cut by an oblique plane.

Fig. 232 shows the plan and elevation of a cylinder cut by the plane **A-B inclined** at 45° to H.P.

Divide the plan circle into any number of equal parts, say twelve, **0.1.2.- - -11.12** and project to corresponding points on the base and line of section in **the** elevation.

Draw **0-12** (Fig. 233) equal to the circumference of the circle and divide it **into 12** equal parts. An approximate division would be to take the chord **between** any of the twelve arcs, say **0-1, 1-2** (Fig. 232) and "*step*" it along **0-12** (Fig. 233).

Erect perpendiculars at **0.1.2 - - - 11.12** (Fig. 233) and project **horizontally from 0'.1'.2'. - - -11'.12'** (Fig. 232) to intersect these perpendiculars giving **corresponding** heights in the development.

Draw a smooth curve through **0'.1'.2' - - -11'.12'.**

The development of the complete cylinder will be rectangle **0.12.12'.0'** and **that** of the cut cylinder (X) will be that portion shown dotted below the curve.

EXERCISE 44 — Use 22″ × 15″ paper — PLATE 55

Fig. 234 shows the junction of two pipes, each $2\frac{1}{2}''$ diam., at right angles forming a square elbow. Draw, to a scale of full size, the given view and add the surface development of pipe ①

The method is exactly the same as that used for Fig. 232 (Plate 54) by regarding the horizontal pipe as having been removed, thus exposing the "line of joint," representing the section of a vertical hollow cylinder.

Fig. 236 shows a right angle bend consisting of three pipes, each $2\frac{1}{4}''$ diam.

Draw, to a scale of full size, the given view and add:—

(a) The surface development of pipe ①

(b) The surface development of the middle section ②

Draw a construction circle $2\frac{1}{4}''$ diam., representing the cross section of the pipe and proceed as for Figs. 234-235 for the surface development of pipe ① (Fig. 237).

Draw the projectors **0.1.2 - - - 11.12** through ① to meet the line of joint with ② and continue to the line of joint between ② and ③ as indicated $\mathbf{2^1.10^1}$ and $\mathbf{4^1.8^1}$.

On the centre line **BA** produced, set off **0-12** equal to the circumference of ② divide it into **12** equal parts in **0.1.2- - - 11.12**, and through these points draw lines perpendicular to **0-12**.

The points $\mathbf{0^1.1^1.2^1}$ **- - -** $\mathbf{11^1.\ 12^1}$, in the development, are obtained by projection from the corresponding points on the lines of joint.

Alternatively these points can be obtained by setting off the distances $\mathbf{0\text{-}0^1}$, $\mathbf{1\text{-}1^1}$, $\mathbf{2\text{-}2^1}$**- - -** $\mathbf{11\text{-}11^1}$, $\mathbf{12\text{-}12^1}$ from the centre line **AB** to the lines of joint on their corresponding perpendicular lines in the development.

Join $\mathbf{0^1.\ 1^1.\ 2^1}$.**- - -**$\mathbf{11^1.\ 12^1}$ with a smooth curve to complete the development of the middle section ② (Fig. 238).

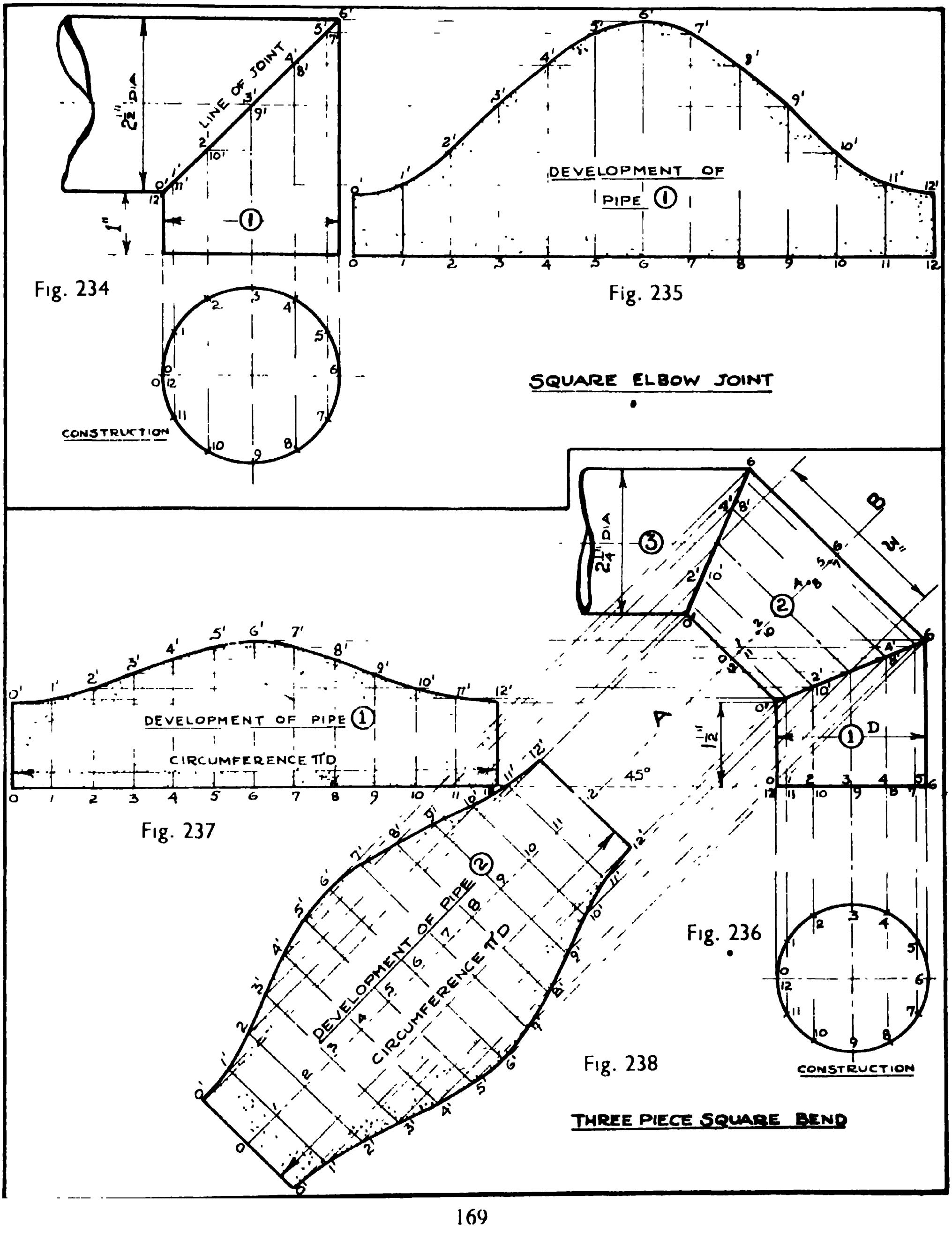


Fig. 234

Fig. 235

SQUARE ELBOW JOINT

Fig. 237

Fig. 236

Fig. 238

THREE PIECE SQUARE BEND

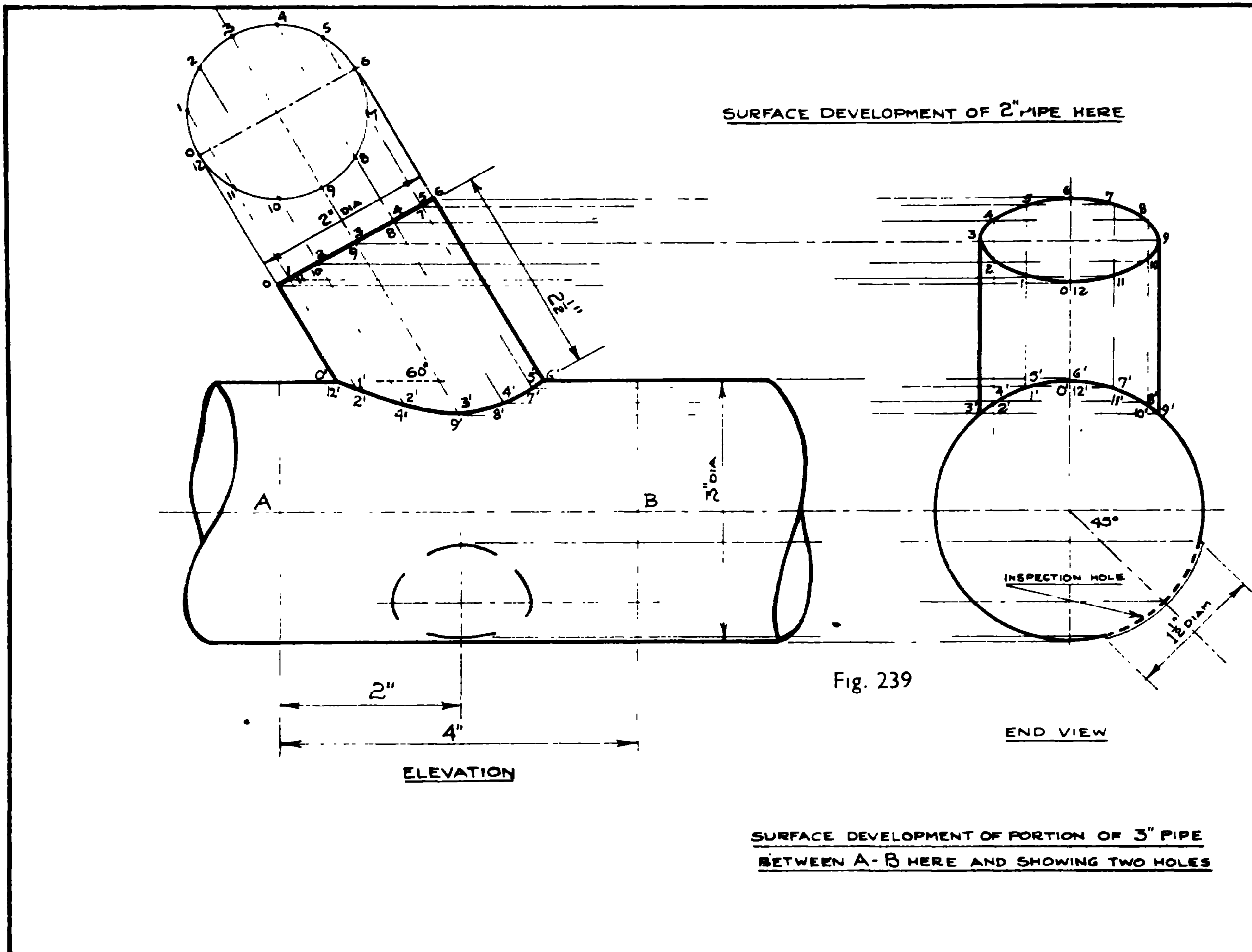
EXERCISE 45 — Use 22″ × 15″ paper — PLATE 56

Fig. 239 shows two views of two pipes meeting at an angle of 60°; there is also a circular hole in the larger pipe

Draw, to a scale of full size, the given views and add:—

(a) The surface development of the smaller pipe.

(b) The surface development of a portion of the larger pipe and showing the true shape of each hole in its correct position on the development.



SURFACE DEVELOPMENT OF 2" PIPE HERE
2" DIA
$2\frac{1}{2}$"
60°
A
B
3" DIA
2"
4"
ELEVATION
45°
INSPECTION HOLE
$1\frac{1}{2}$" DIAM
END VIEW
SURFACE DEVELOPMENT OF PORTION OF 3" PIPE BETWEEN A-B HERE AND SHOWING TWO HOLES

Fig. 239

EXERCISE 46 — Use 22″ × 15″ paper — PLATE 57

Fig. 240 shows a vertical cylinder penetrated by a smaller horizontal cylinder and a square prism. Draw, to a scale of full size, the given views and add:—

(a) The curves of interpenetration between the cylinders and between the square prism and cylinder.

(b) The surface development of the smaller cylinder between **A-B** and the curve of interpenetration (Fig. 241).

(c) The surface development of the square prism between **C-D** and the curve of interpenetration (Fig. 242).

(d) The true shapes of the "holes" in the larger cylinder at the junctions of the smaller cylinder and the square prism with the larger cylinder (Figs. **243, 244**)

Note: You are left to reason out the constructions involved; but should note that the length of the major axis of the ellipse, $\mathbf{0^1}$**-**$\mathbf{6^1}$ (Fig. 243), is equal to the *curved* distance between **6-12** in the plan. The intermediate points, $\mathbf{0.1^1.2^1. - - - 5^1.6}$, correspond to the intermediate *curved* distances **0.1.2. - - - 5.6** in the plan.

Similarly, after dividing one side of the square prism, in the end view, into any number of equal parts, say **5**, the length of the horizontal centre line $\mathbf{5^1}$**-**$\mathbf{15^1}$ in the true shape (Fig. 244) will be equal to the *curved* distance **5-15** in the plan, and the intermediate points $\mathbf{5.4^1.3^1.2^1.0^1}$, etc. on this centre line will correspond to the intermediate *curved* distances in the plan.

After one quarter curve in the true shape has been obtained, the other three are found by continuing the construction, or by the use of tracing paper.

PLATE 57

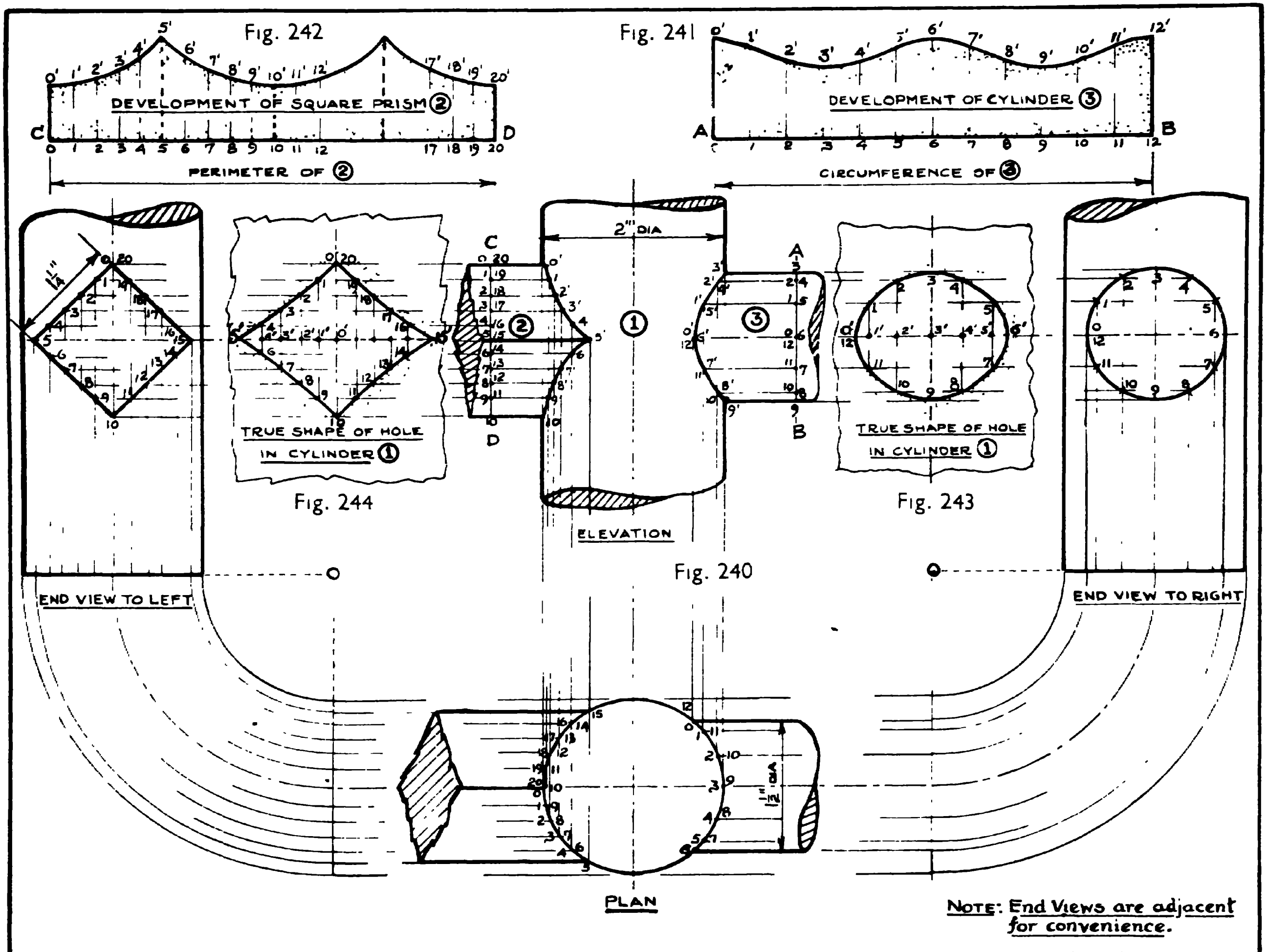


Fig. 242
DEVELOPMENT OF SQUARE PRISM ②
PERIMETER OF ②
Fig. 241
DEVELOPMENT OF CYLINDER ③
CIRCUMFERENCE OF ③
TRUE SHAPE OF HOLE IN CYLINDER ①
Fig. 244
2" DIA
ELEVATION
Fig. 240
TRUE SHAPE OF HOLE IN CYLINDER ①
Fig. 243
END VIEW TO LEFT
END VIEW TO RIGHT
PLAN
NOTE: End Views are adjacent for convenience.

EXERCISE 47 — Use 22″ × 15″ paper — PLATE 58

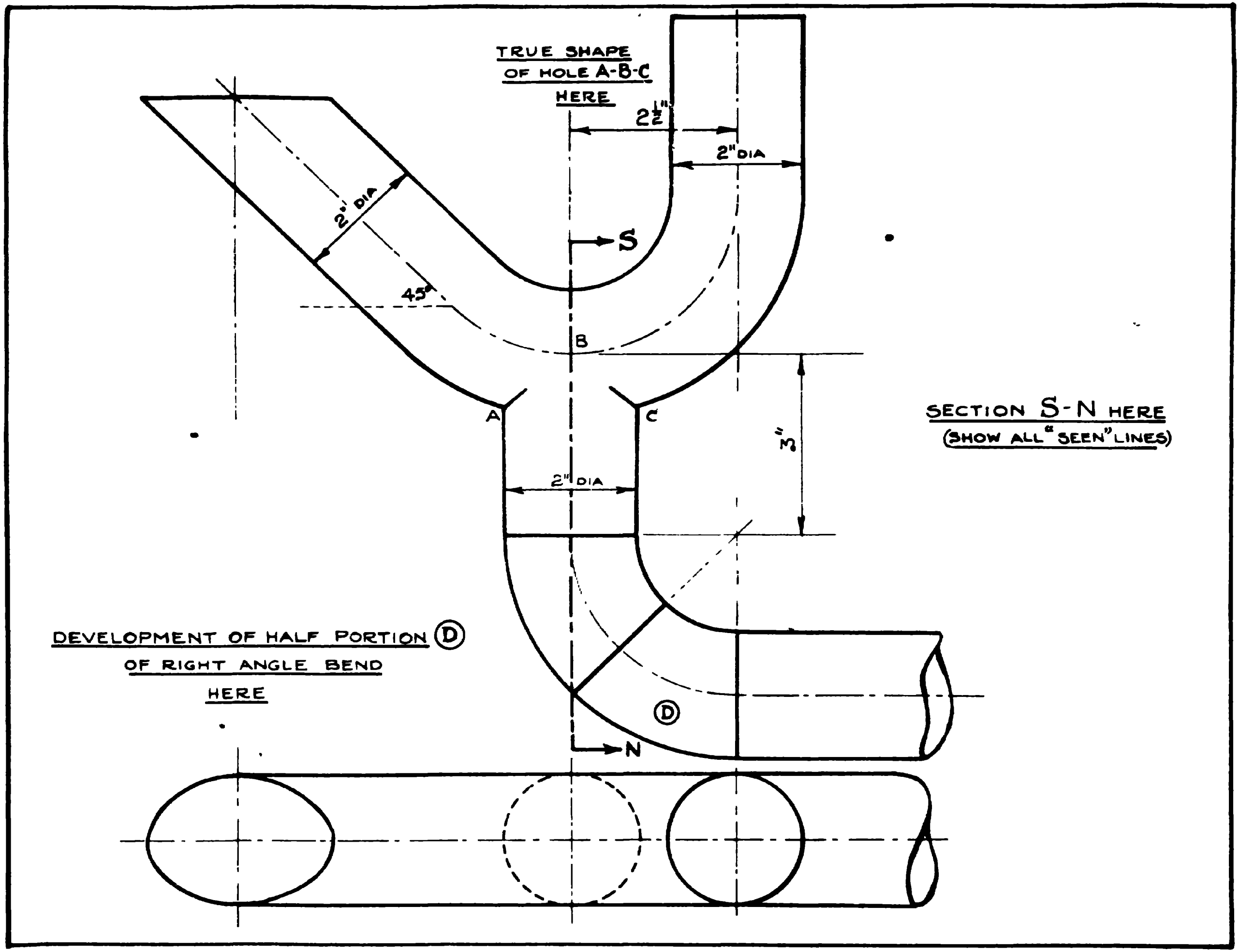
The junction of three pipes of equal diameters is shown. Draw, to a scale of full size, the two given views, including the complete curve of interpenetration at **AC**, and add in the positions indicated:—

(a) The surface development of portion **D** of the right angle bend.

(b) The section taken on the vertical line **S-N** showing all *seen* lines.

(c) The true shape of the hole **ABC**.

PLATE 58



TRUE SHAPE
OF HOLE A-B-C
HERE
$2\frac{1}{2}$"
2" DIA
2" DIA
S
45°
B
A
C
2" DIA
3"
SECTION S-N HERE
(SHOW ALL "SEEN" LINES)
DEVELOPMENT OF HALF PORTION D
OF RIGHT ANGLE BEND
HERE
D
N

SURFACE DEVELOPMENT OF A RIGHT CIRCULAR CONE — PLATE 59

Fig. 245 shows the plan and elevation of a right circular cone. The development of the curved surface is the sector of a circle with a radius equal to the slant height "**R**" (or **A0**^{1}) of the cone, and the length of the arc **0**^{1}**-12**^{1} is equal to the circumference of the base circle.

Divide the base circle into twelve equal parts **0.1.2. - - - 11.12.**

Project these points to the base of the cone and join them to the apex **A** to give twelve equally spaced generators on the cone surface.

With radius **A0**^{1} describe the arc **0**^{1}**-12**^{1} and divide it into twelve equal parts using chord **0-1** or **1-2** (plan) (but see Note below).

Join **A-12**^{1} to form the sector **A.0**^{1}**.12**^{1} giving the surface development of the complete cone.

Join the twelve points on the arc to **A**, thus locating the generators on the development.

Let the cone be cut by an oblique plane **S-N** intersecting the generators in the points **0.1.2. - - - 11.12.**

Through these points draw lines parallel to the base to meet **A0**^{1} and continue them as arcs drawn from **A**.

These arcs meet the generators in the development in the points **1.2. - - - 11.12.**

Join these points with a smooth curve, to give the outline of the trace **S-N** on the cone.

The dotted area of the sector to the right of the curve is the development of the curved surface **B** below the section **S-N**, and that portion to the left of the curved line is that of portion **C** above the section **S-N**.

Mark any point **P** on the surface of the cone and find its position on the plan (**P**^{1}) and on the development (**P**^{3}). The method is similar to that described above. Commence by drawing the generator through **P**, project to the base circle and obtain the plan of the generator and point (**P**^{1}). Find the position of **P**^{2} between the points **3**^{1}**-4**^{1} and finally the position **P**^{3} in the development.

Fig. 246 shows the slotted frustum of an inverted cone.

Draw, to a scale of full size, the given view and add:

(a) The plan showing hidden lines.

(b) The development of the curved surface.

Note. The length of arc 0^1 - - - 12^1, in the development, will not be exactly equal to the circumference of the base circle (representing the plan of the cone) because equal chords do not cut off equal arcs on circles of different radii ; but this construction will generally serve the purpose.

In order that the length of the development arc may be exactly equal to the circumference of the plan circle, the development arc can be set out by determining the value of the angle θ thus:—

Arcs are proportional to the angles which they subtend at the centre of a circle :

$$2\pi r : \theta :: 2\pi R : 360$$

$$\theta \quad (360 \times \frac{r}{R}) \text{ degrees.}$$

$$140^\circ.$$

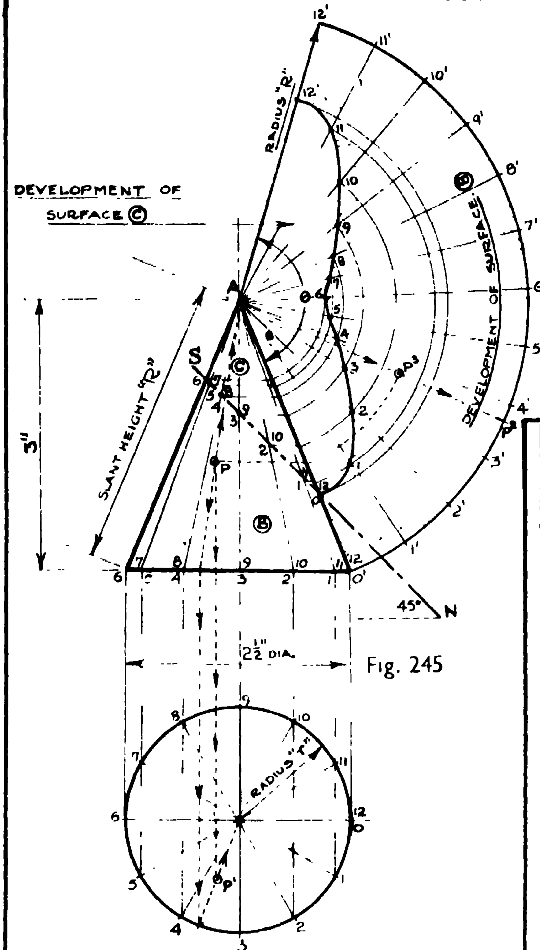


Fig. 245

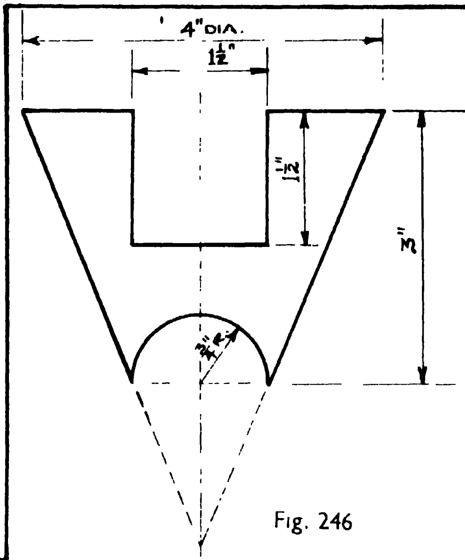


Fig. 246

PLAN HERE

SURFACE DEVELOPMENT HERE

EXERCISE 48 — Use 22″ × 15″ paper — **PLATE 60**

Fig. 247 shows the elevation of a semi-circular tower surmounted by a conical turret. The tower projects from the wall of a building and the turret is cut by the sloping roof. Draw, to a scale of $\frac{1}{2}''$ to a foot, the given view and add:—

(a) The plan.

(b) The true shape of the hole in the roof.

(c) The development of the curved surface of the turret.

Fig. 248 shows the view of a cylinder with two pieces removed.

Draw, to a scale of full size, the given view and add:—

(a) The plan.

(b) The end view.

(c) The development of the curved surface of the cut cylinder.

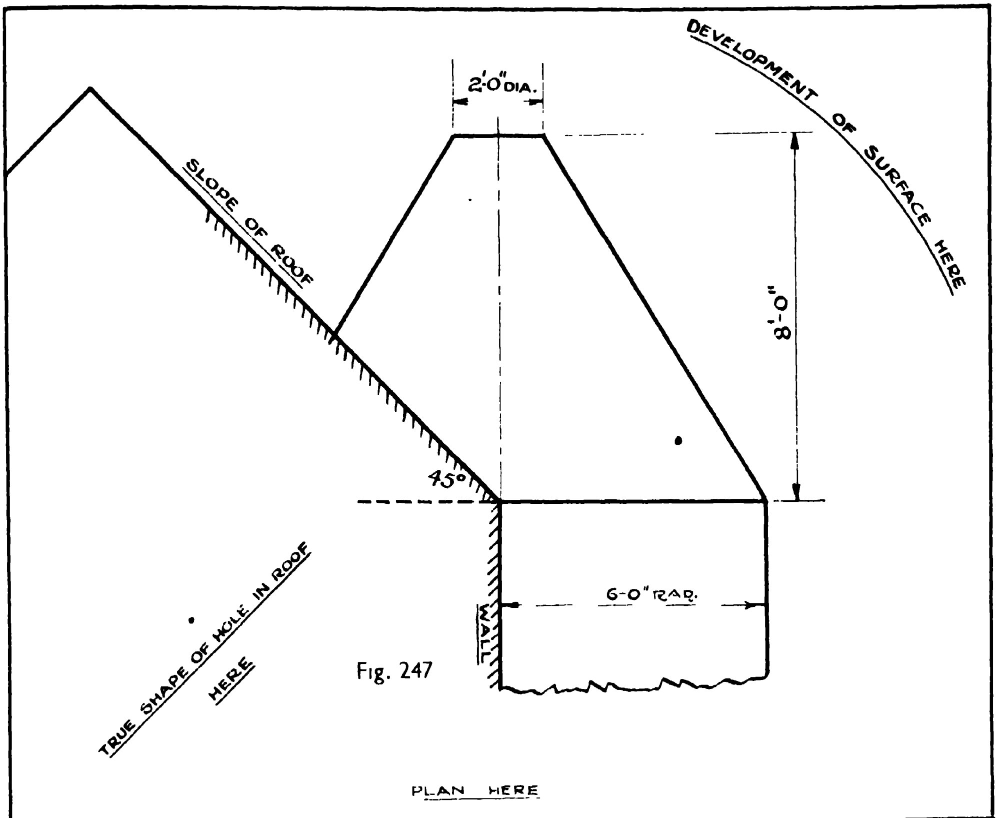


Fig. 247

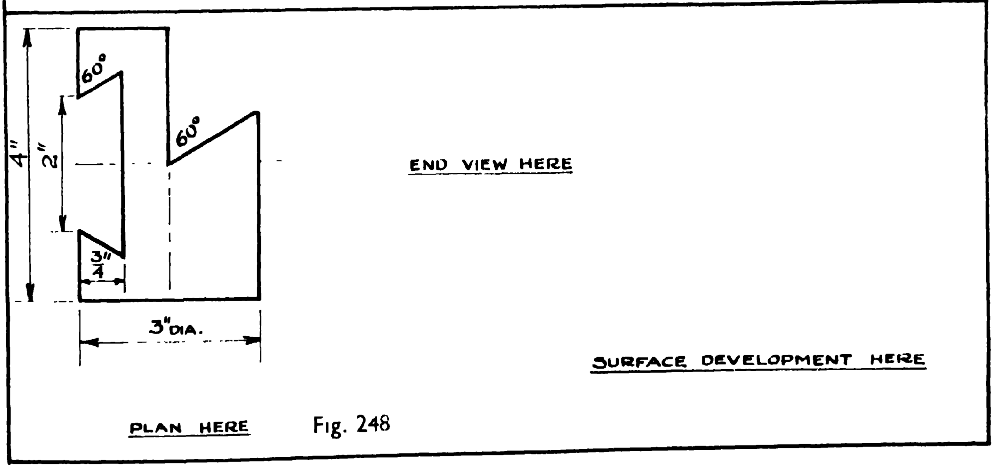


Fig. 248

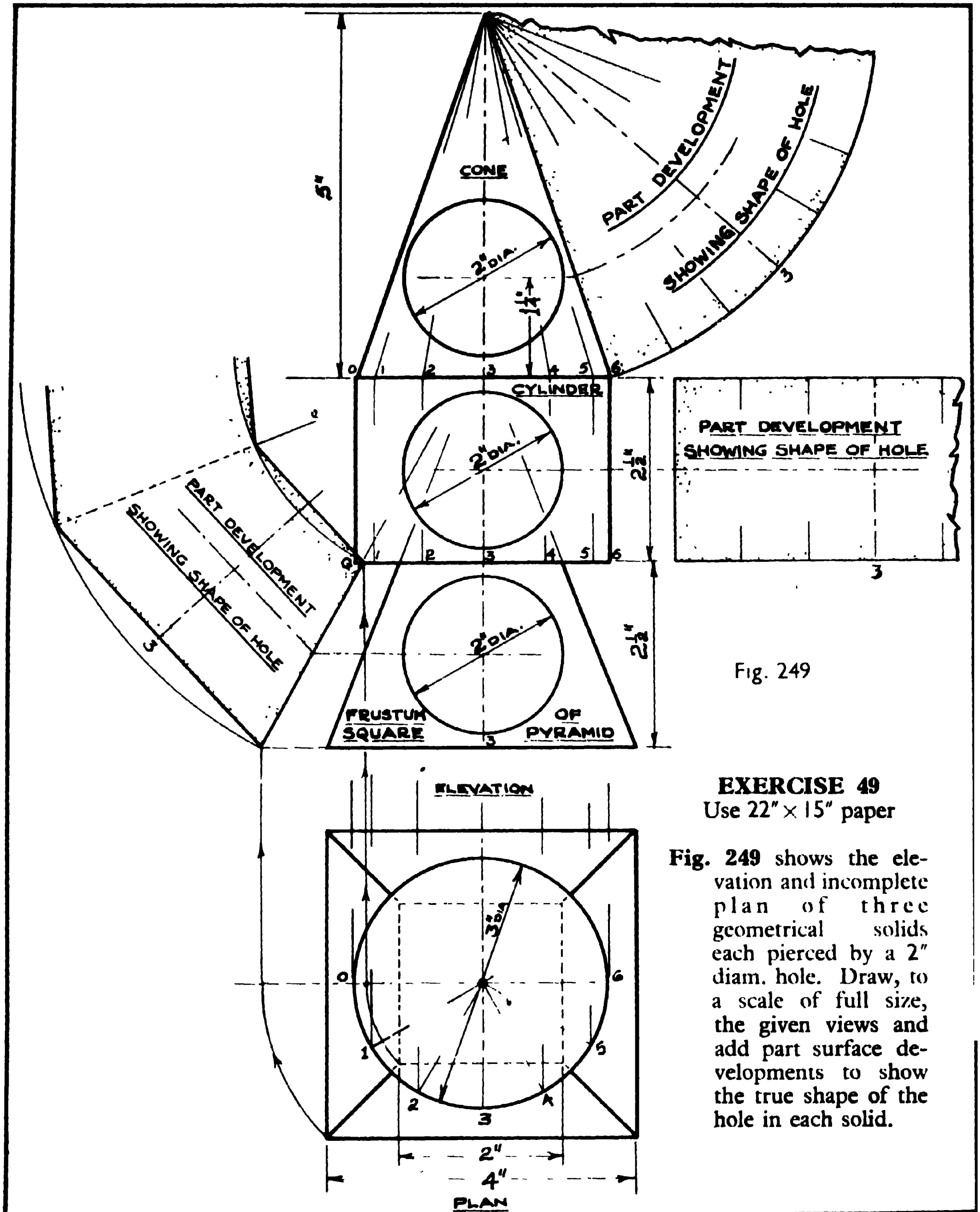


Fig. 249

EXERCISE 49
Use 22" × 15" paper

Fig. 249 shows the elevation and incomplete plan of three geometrical solids each pierced by a 2" diam. hole. Draw, to a scale of full size, the given views and add part surface developments to show the true shape of the hole in each solid.

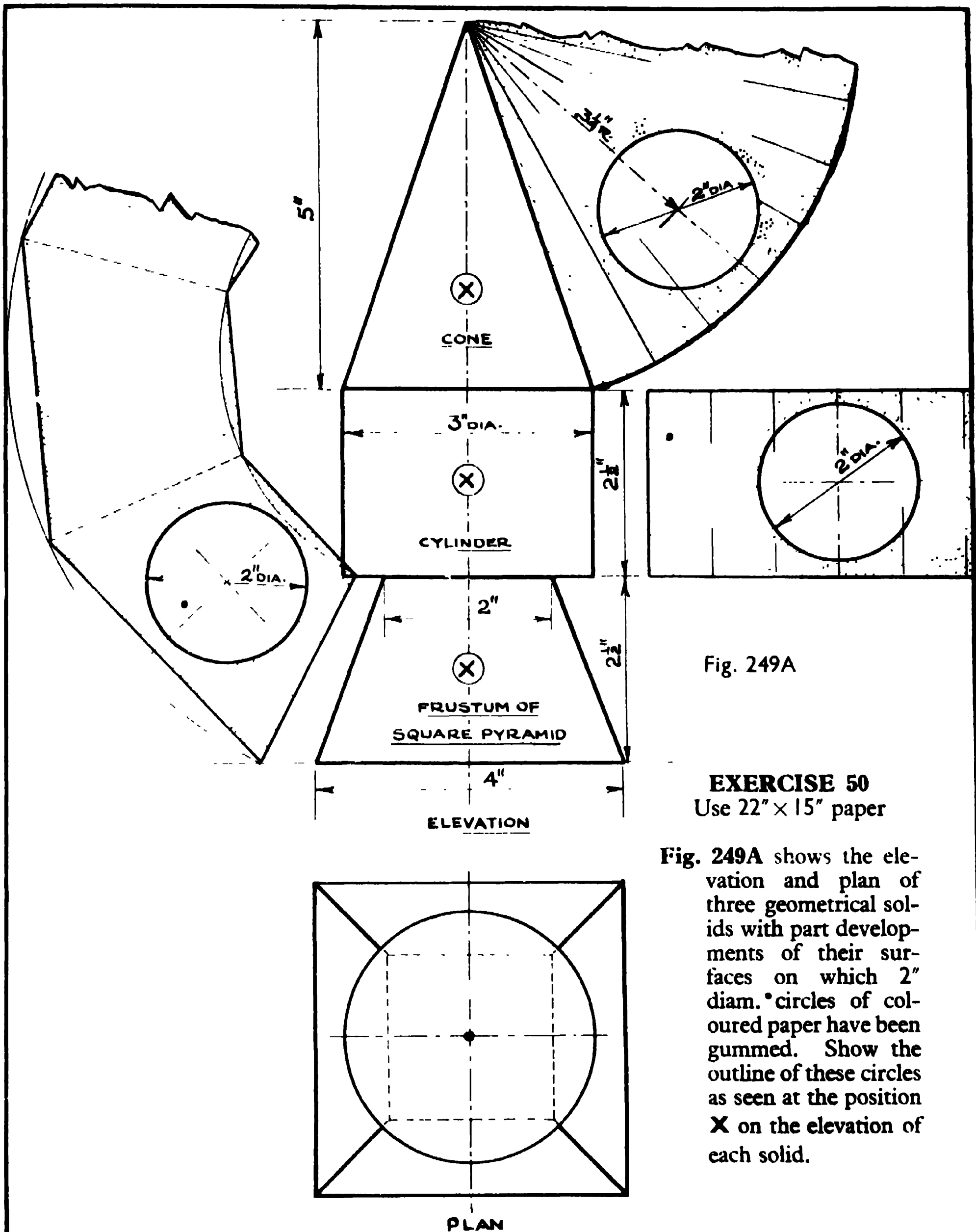


Fig. 249A

EXERCISE 50
Use 22" × 15" paper

Fig. 249A shows the elevation and plan of three geometrical solids with part developments of their surfaces on which 2" diam. circles of coloured paper have been gummed. Show the outline of these circles as seen at the position **X** on the elevation of each solid.

EXERCISE 51 — Use 22″ × 15″ paper — PLATE 63

Fig. 250 shows the elevation of an inverted sheetmetal conical funnel on which the letter **W** is to be fixed. The five points represent positions for locating the letter.

Draw, to a scale of full size, the given elevation and add:—

(a) The part surface development locating the points and the shape of the letter **W**.

(b) The plan locating the points and the shape of the letter **W**.

Fig. 251 shows the elevation of a party hat on which coloured paper, to show as a letter **D**, has been gummed.

Draw, to a scale of half full size, the given elevation and add:—

(a) The part surface development showing, in position, the outline of the letter **D**.

(b) The plan showing, in position, the outline of the letter **D**.

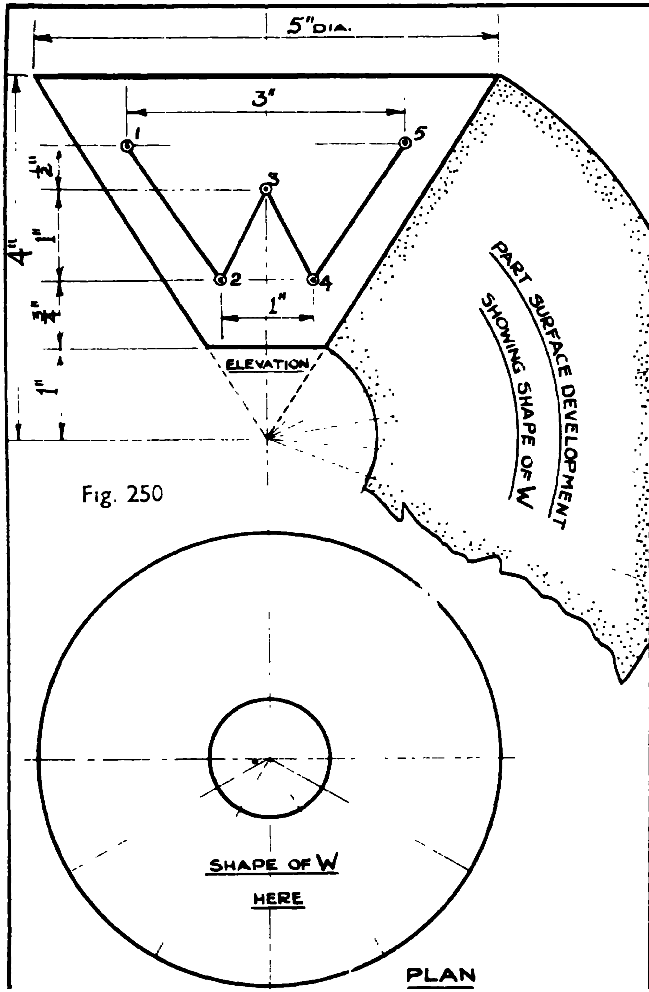


Fig. 250

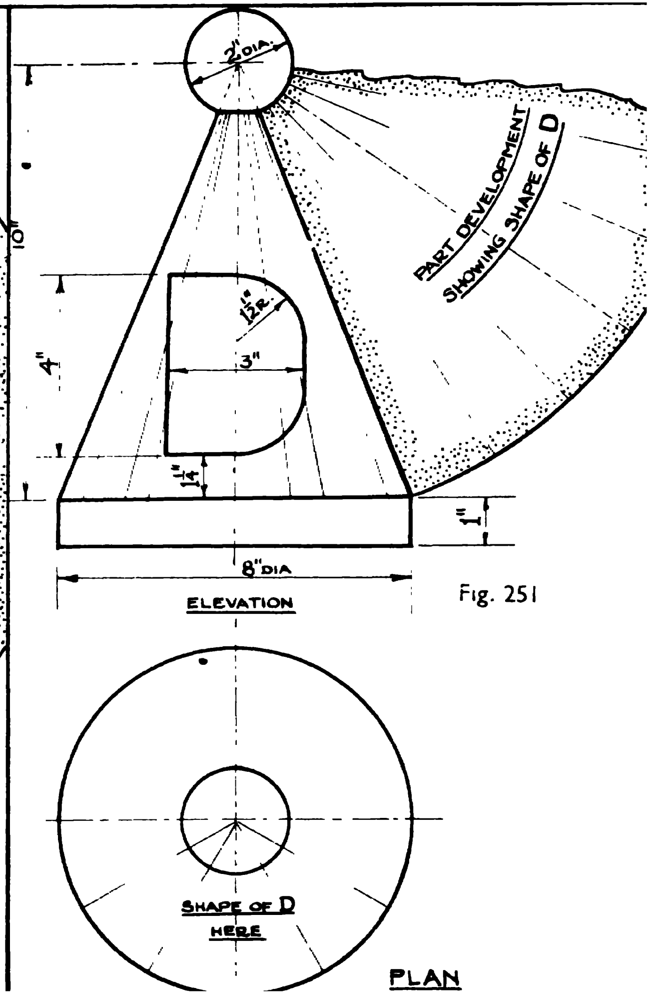


Fig. 251

INTERPENETRATION OF CYLINDER AND CONE

The relative sizes and positions of the cone and cylinder enable the curves of intersection to be considered under three groups (1) *when the cone envelops the cylinder* (2) *when the cylinder envelops the cone* (3) *when the cylinder and cone envelop a common sphere.*

EXERCISE 52 — Use 22″ × 15″ paper — PLATE 64

To draw the curves of interpenetration of a cylinder and cone when the cone envelops the cylinder.

(a) **Fig. 252** shows the three views of a right circular cone penetrated by a cylinder. The axis of the cylinder is at right angles to that of the cone.

The procedure is to obtain the curves of interpenetration by considering section planes parallel to the axis of the cylinder and to the base of the cone.

Divide the circle (end view) into twelve parts, **0.1.2. - - - 10.11.12.** It is not essential that the parts should be equal—points taken at random, or as otherwise convenient, will serve just as well.

Consider the horizontal section plane **5-7** (end view) which passes through the point **G** on the slant edge of the cone (elevation).

Project from **5** and **7** to the base of the cone, and continue to $\mathbf{5^1}$ and $\mathbf{7^1}$ in the plan.

Project from **G** (elevation) to $\mathbf{G^1}$ on the centre line of the plan.

With centre **O** and radius $\mathbf{OG^1}$ describe an arc cutting the horizontal projectors from $\mathbf{7^1}$ and $\mathbf{5^1}$ in the points **7** and **5** giving two points on the curve of interpenetration in plan (left side).

Draw projectors upwards from these points to cut the corresponding horizontal projector through **5.7** (end view) giving the points **5** and **7** (hidden) on the curve of interpenetration in elevation.

Other points on the curves can be obtained by similar methods as indicated in Fig. 252.

Note: *One of the horizontal section planes should include the "key" points* **X** *and* **Y** *(end view). They are the nearest points on the circle to the slant edges of the cone and are therefore limiting points on the curves of interpenetration.*

The point **X** is located on the circle at the point of tangency (end view) (Can you calculate the value of the angle α ?)

The method of fixing these "key" points on the curves of interpenetration is similar to that for the points **5** and **7** and is indicated by broken-line projectors and directional arrows.

(b) Complete the two similar curves of interpenetration in plan and elevation.

(c) Draw the true shape of the hole in the cone in the position shown.

(d) Complete the section on **S-N** showing hidden lines.

(e) Draw the surface development of cylinder ①.

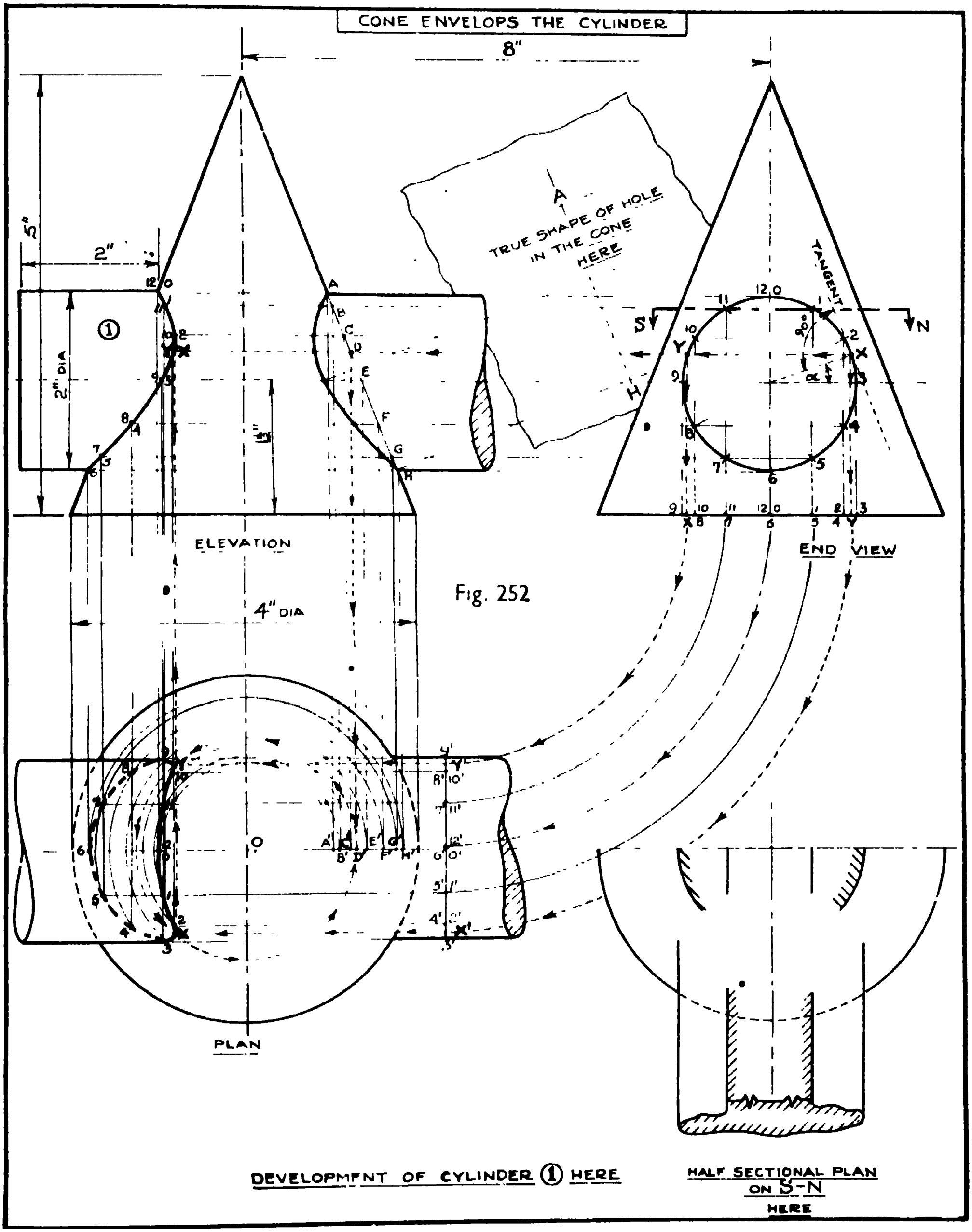

CONE ENVELOPS THE CYLINDER
8"
5"
2"
½"
2" DIA
4" DIA
1½"
ELEVATION
TRUE SHAPE OF HOLE IN THE CONE HERE
TANGENT
S
N
END VIEW
PLAN
DEVELOPMENT OF CYLINDER ① HERE
HALF SECTIONAL PLAN ON S-N HERE

Fig. 252

EXERCISE 53 — Use 22″ × 15″ paper — PLATE 65

To draw the curves of interpenetration of a cylinder and cone when the cylinder envelops the cone.

(a) **Fig. 253** shows the three views of a right circular cone penetrated by a cylinder. The axis of the cylinder is at right angles to that of the cone.

Commence by dividing the circle (end view) into a number of parts, which should include the "key" points **2.14** and **5.11** where the circle cuts the slant edges of the cone, and so determine the limits of the curves of interpenetration.

Follow the methods which are described in detail for Exercise **52** (Plate **64**) to obtain the points required to draw the curves.

(b) Draw the development of the top portion of the cone.

(c) Complete the section **S-N** showing hidden lines.

(d) Draw the development of portion **X-Y** of the cylinder.

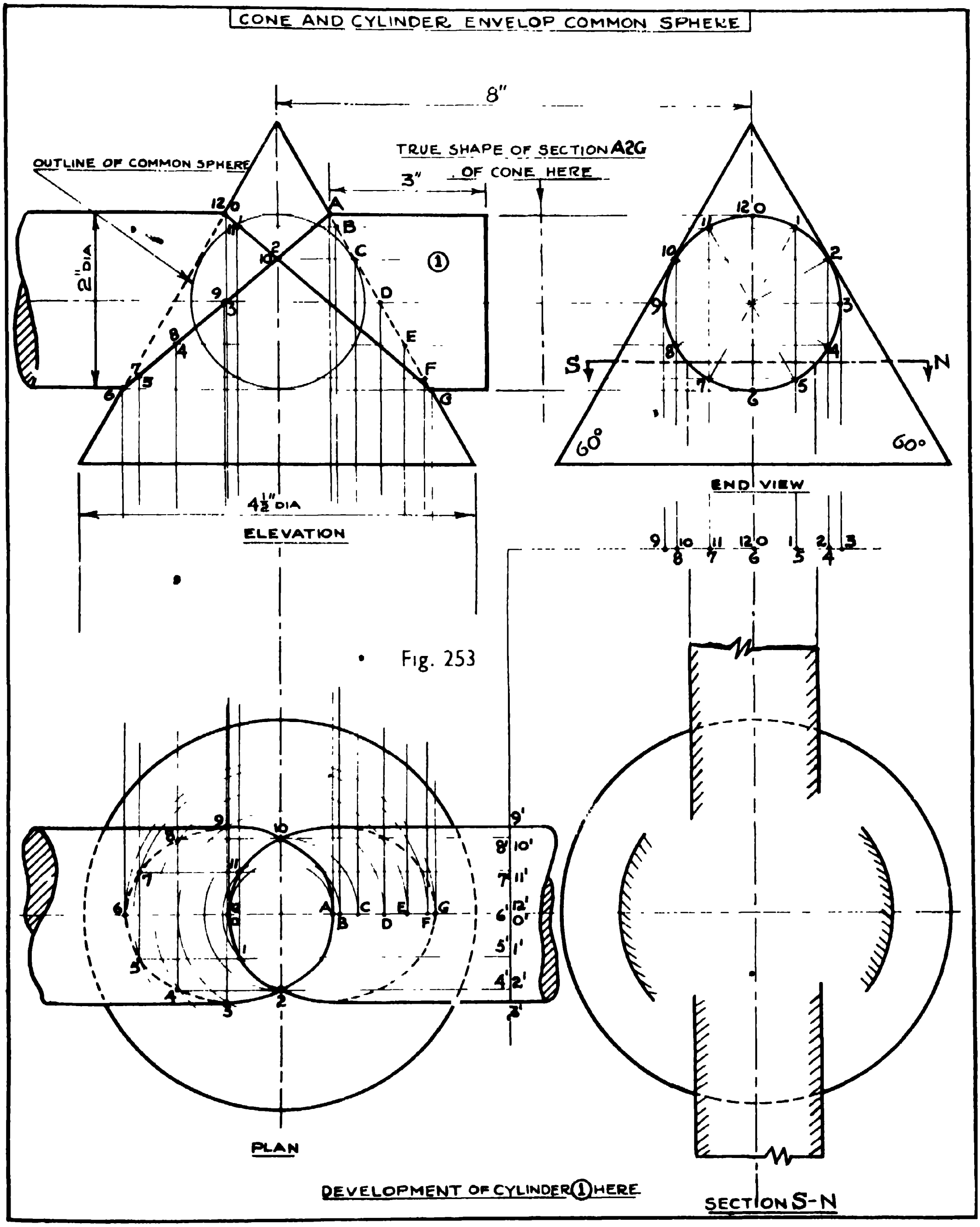

CONE AND CYLINDER ENVELOP COMMON SPHERE
8"
TRUE SHAPE OF SECTION A2G
OF CONE HERE
OUTLINE OF COMMON SPHERE
3"
2" DIA
4½" DIA
ELEVATION
END VIEW
60°
60°
S
N
PLAN
DEVELOPMENT OF CYLINDER ① HERE
SECTION S-N

Fig. 253

EXERCISE 54 — Use 22″ × 15″ paper — PLATE 66

To draw the lines of interpenetration of a cylinder and cone when they envelop a common sphere.

Refer to note on page 184.

(a) **Fig. 254** shows the three views of a right circular cone penetrated by a cylinder. The axis of the cylinder is at right angles to that of the cone.

The circle in the end view is such that the slant edges of the cone are tangential to it, thus locating the "key" points **2.10**.

Commence by selecting a number of other points on the circle, and follow the methods which are described in detail for Exercise **52** (Plate **64**) to obtain the points required to draw the lines of interpenetration. In this case the "curves" are straight lines in the elevation.

(b) Draw the true shape on a section **A.2.G** of the cone.

(c) Complete the section **S-N** showing hidden lines.

(d) Draw the development of cylinder ①.

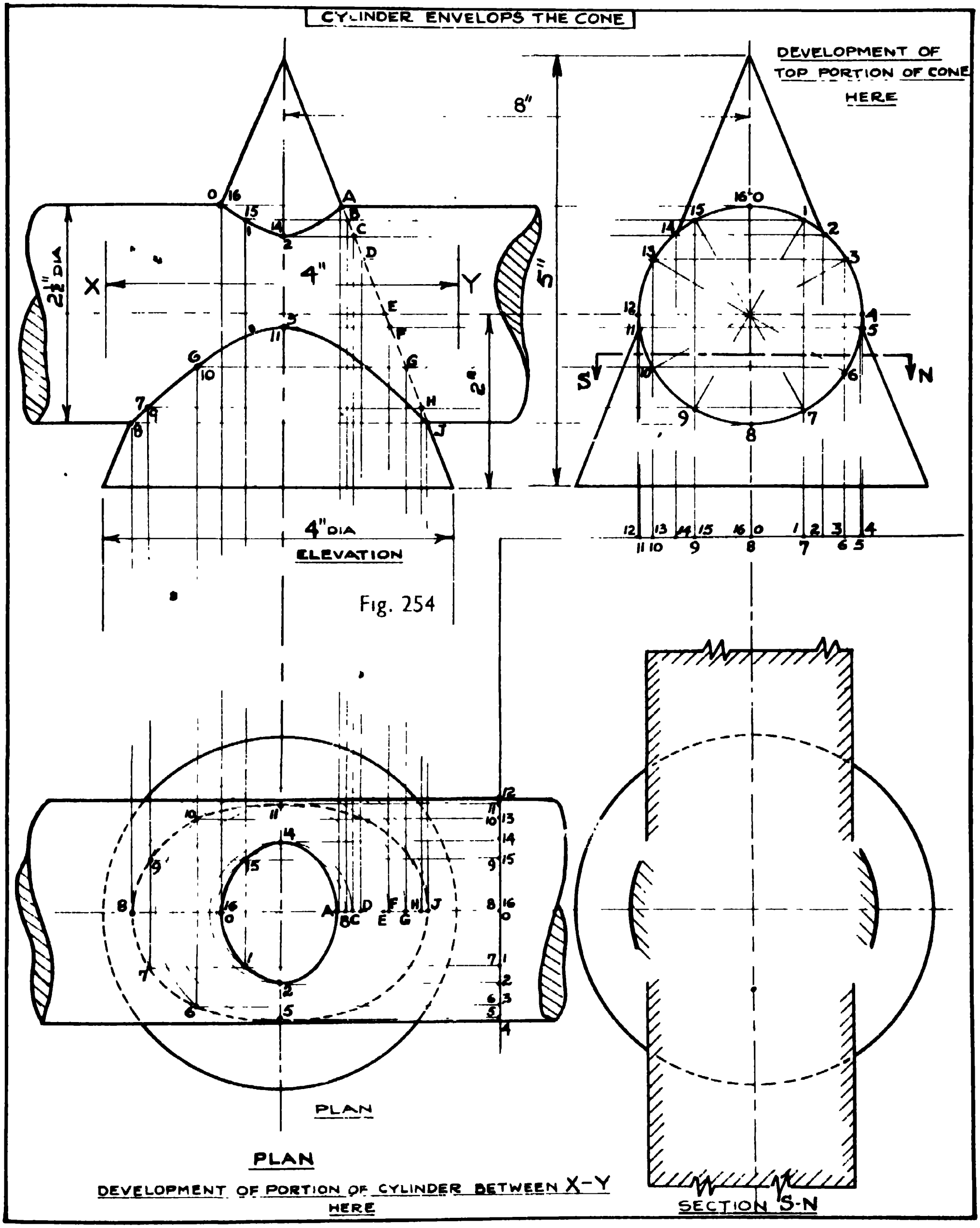

CYLINDER ENVELOPS THE CONE
DEVELOPMENT OF TOP PORTION OF CONE HERE
8"
4"
X
Y
$2\frac{1}{2}$" DIA
5"
2"
4" DIA
ELEVATION
S
N
PLAN
PLAN
DEVELOPMENT OF PORTION OF CYLINDER BETWEEN X-Y HERE
SECTION S-N

Fig. 254

INTERPENETRATION OF CYLINDER AND SPHERE

EXERCISE 55 — Use 22″ × 15″ paper — PLATE 67

To draw the curves of interpenetration of a horizontal cylinder and a hemisphere.

(a) **Fig. 255** shows the elevation of a hemisphere penetrated horizontally by a cylinder, $1\frac{1}{2}''$ diam.

Divide the circle, representing a section of the cylinder, into a number of parts and consider the horizontal section through **2.10** which meets the edge of the hemisphere in **C**.
Project from **2** and **10** to the same numbers on the horizontal line below the circle and transfer them to **2**^{1} and **10**^{1} in the plan.
Project from **C** to **C**^{1} on the centre line (plan).
With centre **O** and radius **OC**^{1} describe an arc cutting the projectors from **2**^{1}**.10**^{1} in the points **2**^{1}**.10**^{1} giving two points on the curve of interpenetration in plan.
Draw projectors upwards from these points to cut the corresponding horizontal projector through **2.10** giving the points **2** and **10** (hidden) on the curve of interpenetration in elevation.
Other points on the curves can be obtained by similar methods as indicated in Fig. 255.

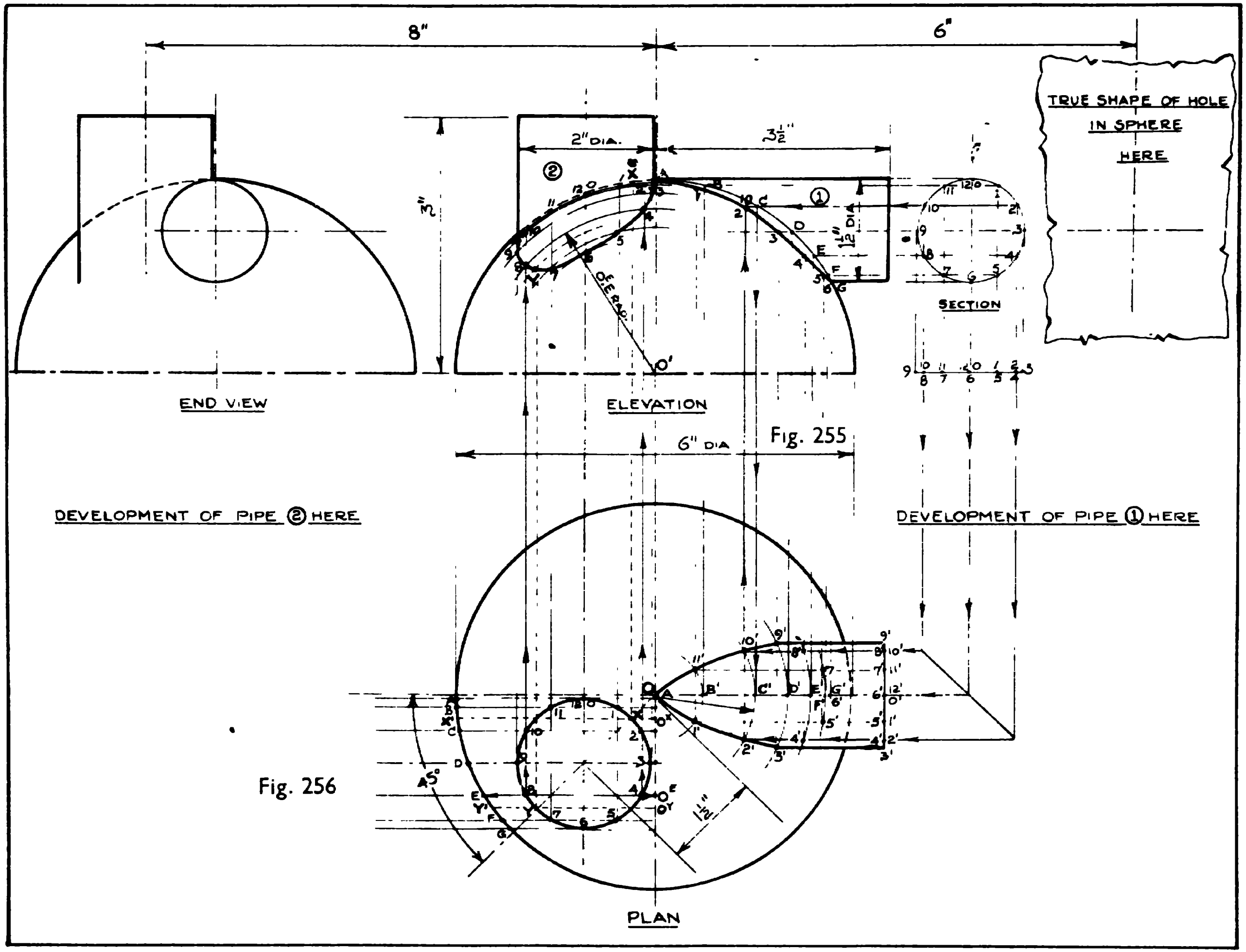
(b) **Fig 256 shows the plan of the hemisphere penetrated vertically by a cylinder, 2″ diam.**

Divide the circle (plan) into a number of parts, which should include the "key" points **X** and **Y** on the 2 diameter which passes through **O**, the centre of the hemisphere. They are limiting points, representing the highest and lowest points respectively, on the curve of interpenetration.
Consider the vertical section through **4.8** which meets the edge of the hemisphere in **E**.
Project upwards from **4** and **8** to the elevation.
With radius **O**^{E}**E** and centre **O**^{1} (elevation) describe an arc cutting the projectors from **4** and **8** giving the similarly numbered points on the curve of interpenetration.
Other points on the curve can be obtained by similar methods, as indicated in Fig. 256. *Your attention is drawn to the broken-line projectors used to locate the "key" points* **X** *and* **Y**.

(c) Complete the end view.

(d) Draw the approximate true shape of the hole in the hemisphere **A-G.**

(e) Draw the development of each cylinder.


8"
6"
TRUE SHAPE OF HOLE
IN SPHERE
HERE
2" DIA.
$3\frac{1}{2}$"
3"
$1\frac{1}{2}$" DIA
O.E RAD.
SECTION
END VIEW
ELEVATION
6" DIA
Fig. 255
DEVELOPMENT OF PIPE ② HERE
DEVELOPMENT OF PIPE ① HERE
Fig. 256
45°
$1\frac{1}{2}$"
PLAN

EXERCISE 56 — Use 22" × 15" paper — PLATE 68

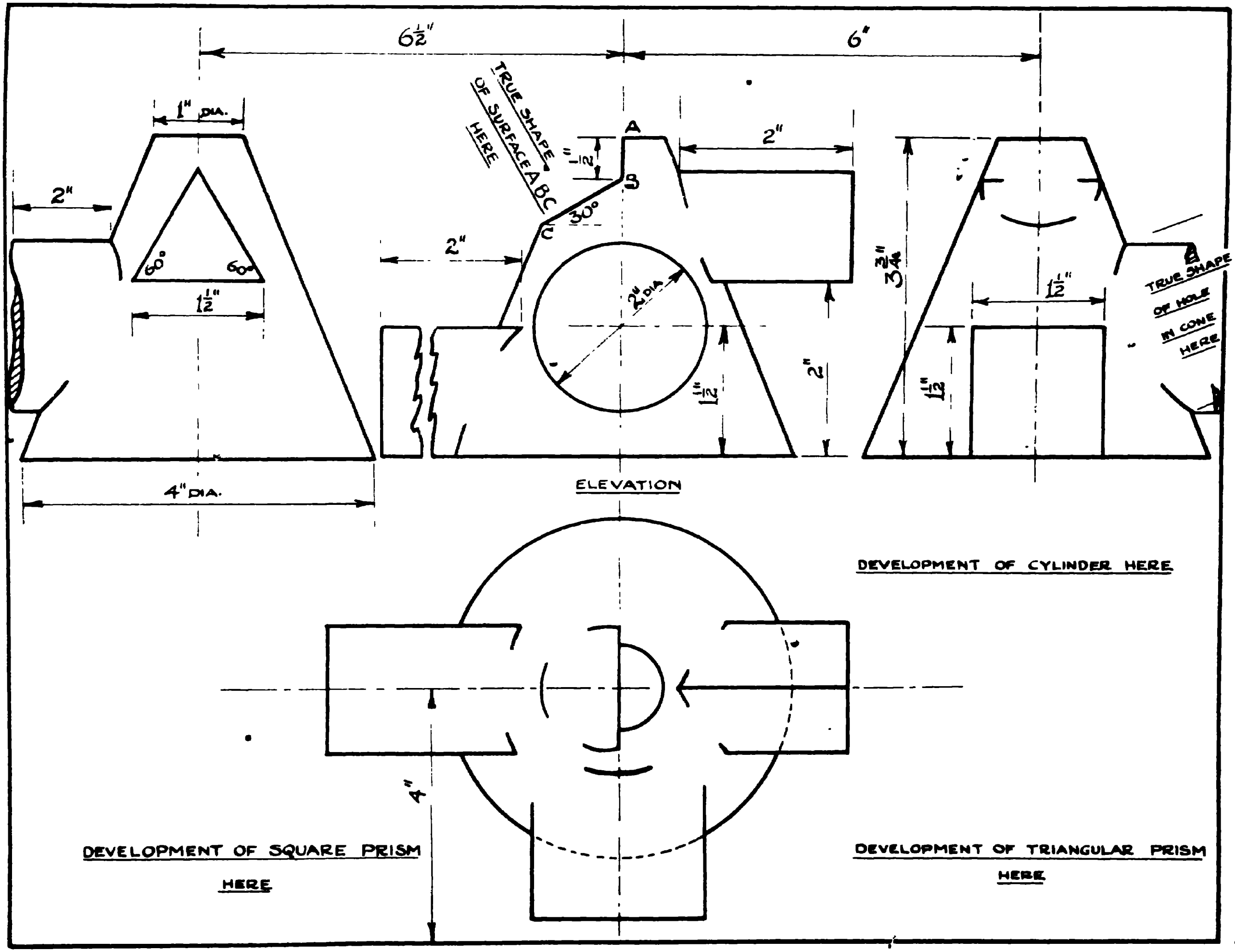
This is a general revision exercise. The four views indicate an arrangement whereby the cut frustum of a cone is penetrated by a cylinder, square prism and an equilateral triangular prism.

Draw the given arrangement and complete all curves of interpenetration, then add:—

(a) The two required true shapes.

(b) The three required developments.

(c) Remove all construction lines to leave neat finished drawings.


6½"
6"
1" DIA.
2"
60°
60°
1½"
4" DIA.
TRUE SHAPE
OF SURFACE ABC
HERE
A
B
C
½"
30°
2"
2"
2" DIA.
1½"
2"
3¾"
1½"
1½"
TRUE SHAPE
OF HOLE
IN CONE
HERE
ELEVATION
DEVELOPMENT OF CYLINDER HERE
4"
DEVELOPMENT OF SQUARE PRISM
HERE
DEVELOPMENT OF TRIANGULAR PRISM
HERE

FILLET CURVES

This type of curve occurs frequently in technical drawing, e.g., when engineering parts are finished by turning in a lathe. It provides strength by having the corners *swept-up*, or thickened, with additional metal.

EXERCISE 57 — Use 22″ × 15″ paper (vertically) — PLATE 69

To draw the curve of interpenetration of a circular fillet and a plane surface.

Fig. 257 shows three views of the *palm*, or *tee*, end of an engine connecting rod. The circular *shank* has been turned so that it merges into the plane surface of the end.

Draw the fillet curve and mark the points of tangency at **A** and **B**.

$\mathbf{P^3}$ is the *key* point on the curve of intersection and should be fixed first.

With centre **O** and radius **OP**, describe an arc meeting the centre line through the plan in $\mathbf{P^1}$.

From $\mathbf{P^1}$ draw the vertical projector meeting the fillet curve in $\mathbf{P^2}$.

Through $\mathbf{P^2}$ draw a horizontal projector to meet the centre through the elevation in the required point $\mathbf{P^3}$, giving the highest point in the curve.

Select a few points on the fillet curve between $\mathbf{P^2}$ and **B**, e.g., **1** and **2**.

Consider the horizontal section through **2**.

Draw a vertical projector from **2** to $\mathbf{2^1}$, and with centre **O** and radius $\mathbf{O2^1}$ describe an arc meeting the edge of the plane surface of the *tee* end in $\mathbf{2^2}$.

Draw a vertical projector from $\mathbf{2^2}$ (broken line) to meet the horizontal line through **2** (elevation) in $\mathbf{2^1}$, giving a point on the curve of interpenetration.

Other points are obtained by the same method. Half the curve is shown $\mathbf{B^1.2^1.1^1.P^3}$.

The fillet curve in the end view is determined by projection from $\mathbf{P^3}$ to $\mathbf{P^1}$.

Fig. 258. Complete the curves of interpenetration in plan and elevation when a circular shaft meets a plane surface which is triangular in section.

Commence by fixing *key* points on the required curves.

PLATE 69

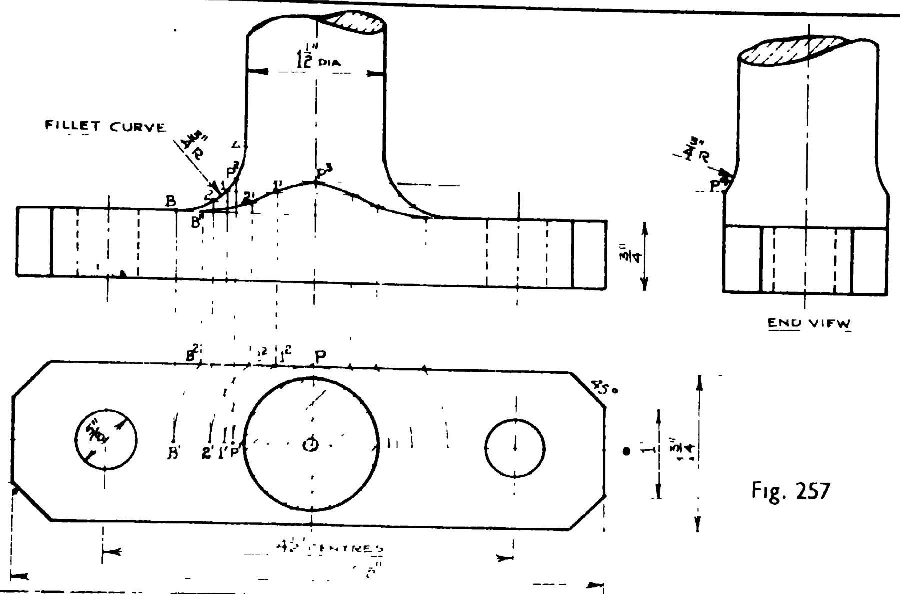


Fig. 257

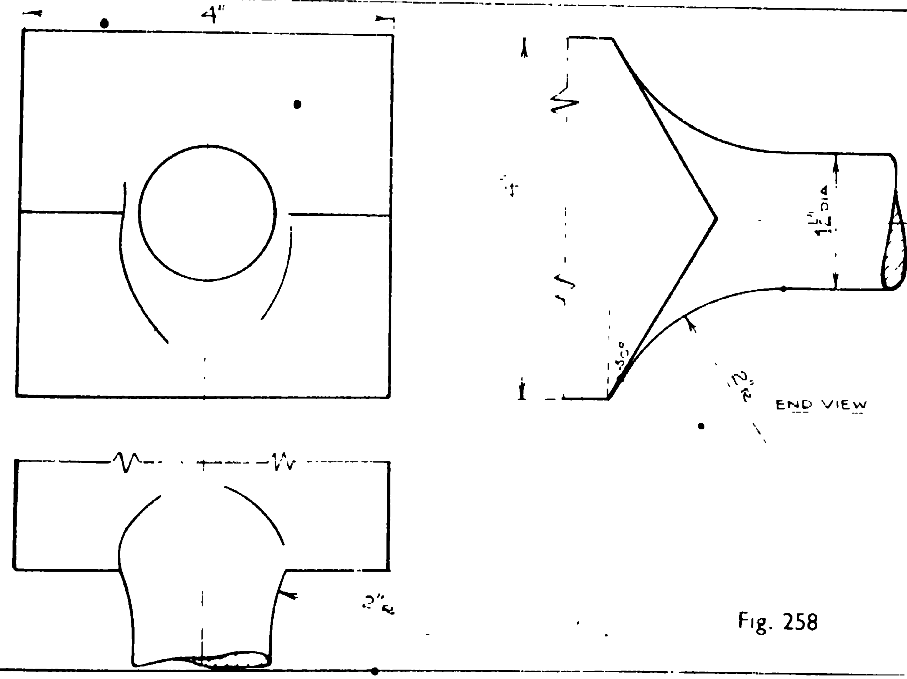


Fig. 258

EXERCISE 58 — Use 22″ × 15″ paper (vertically) — **PLATE 70**

To draw the curve of interpenetration of a circular fillet and a cylindrical surface.

Fig. 259 shows the elevation and end view of an engine "*crank*". Draw, to a scale of half full size, the given views and mark points of tangency as shown at **T**.

Select a number of points on the fillet curve **T-T** (end view) say **1.2 - - - 5**.

The highest point **P** on the curve of interpenetration is obtained by drawing a projector (broken line) from **T**^{2} (elevation) to meet the vertical line through **T** (end view).

Consider the vertical section through **3**.

Draw a horizontal projector from **3** to **3**^{1}, and with centre **O** and radius **03**^{1}, describe an arc meeting sloping edge of the "*web*" in **3**^{2}.

Draw a horizontal projector (broken line) to meet the vertical line through **3** (end view) in **3**^{1}, giving a point on the curve of interpenetration.

Other points are obtained by the same method to give the required curve **1**^{1}**.2**^{1}**. - - - P**.

The curve **AB**, on the "*boss*" for the crank pin, should be drawn by similar methods.

Fig. 260 shows the plan and elevation of a "*box*" key suitable for $\frac{3}{4}$″ Whitworth hexagon nut. Draw, to a scale of full size, the given views, mark all points of tangency with a heavy dot and show construction for obtaining the curve of interpenetration.

Fig. 261 shows the handle of a screw driver. Draw, to a scale of full size, the given views and complete the curve of interpenetration between **A-B** in the elevation.

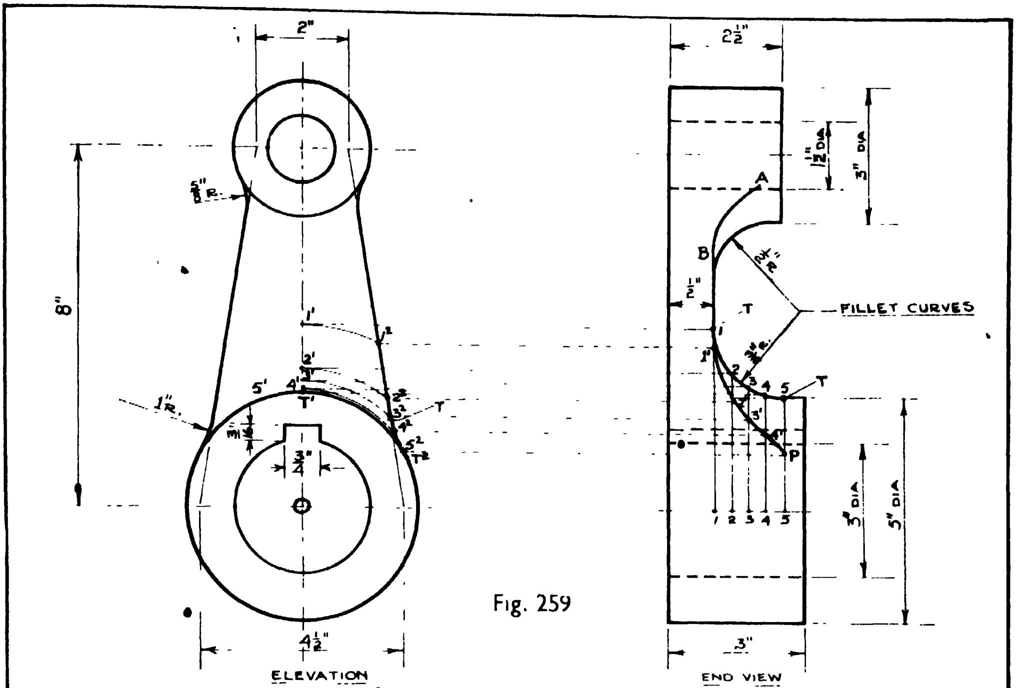


Fig. 259

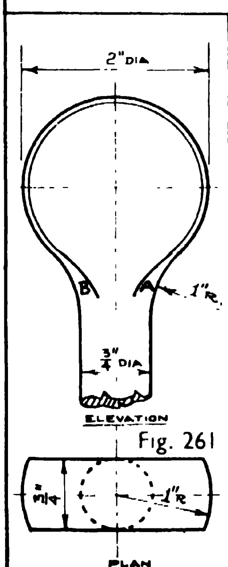


Fig. 261

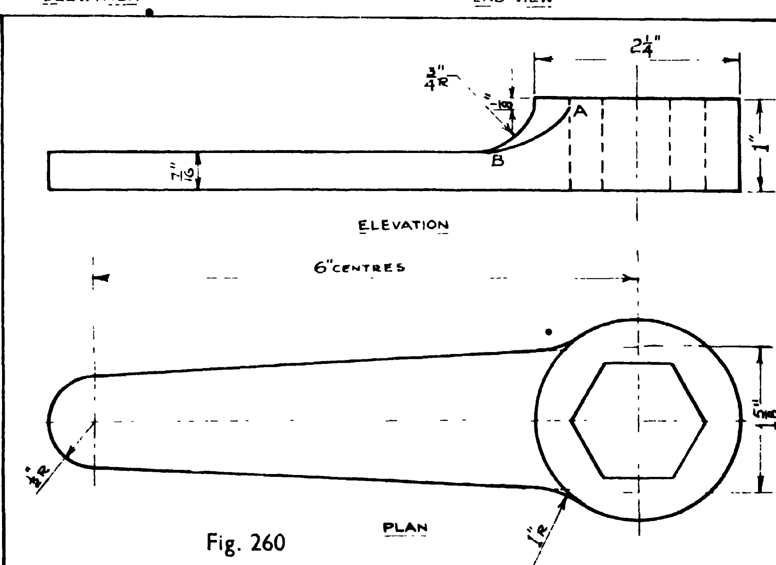


Fig. 260

CHAPTER 8

OBLIQUE PYRAMIDS — OBLIQUE CONE — TRANSITION PIECES

When the axis of a pyramid or a cone is inclined to the base, it is referred to as *oblique* pyramid or an *oblique* cone.

OBLIQUE RECTANGULAR PYRAMID

EXERCISE 59 — Use half 22″ × 15″ paper — PLATE 71

Fig. 262 shows the plan and elevation of an oblique rectangular pyramid cut by a plane EF. Draw the surface development of the pyramid and of the portion below EF.

The sloping edges of the pyramid are inclined to both planes so it is necessary to find their true lengths. Consider the edge **PA**.

With centre $\mathbf{P^1}$ (plan) and radius $\mathbf{P^1A}$, draw an arc meeting the centre line through $\mathbf{P^1}$ in $\mathbf{A^1}$ and continue vertically to meet the base line in $\mathbf{A^2}$ (elevation).

$\mathbf{PA^2}$ is the true length of **PA** and also of **PD**.

The true length of **PB** is obtained by the same method and can be followed from the drawing at $\mathbf{PB^2}$ (elevation). The true length of **PC** is also equal to that of **PB**.

The complete development can now be drawn, commencing with $\mathbf{PA^2}$. (Fig. 263)

With centre **P** and radius $\mathbf{PB^2}$ describe an arc, and with centre $\mathbf{A^2}$ and radius **3″** (side **AB** of base), cut the arc in $\mathbf{B^1}$.

Join $\mathbf{PB^1}$ and $\mathbf{A^2B^1}$.

With centre **P** and radius $\mathbf{PB^1}$ (also true length of **PC**) describe an arc, and with centre $\mathbf{B^1}$ and radius $2\frac{1}{2}$″ (side **BC** of base) cut the arc in $\mathbf{C^1}$.

Join $\mathbf{PC^1}$ and $\mathbf{BC^1}$.

The other half of the development is obtained by similar methods to give the complete surface development $\mathbf{P.A^2.B^1.C^1.D^1.A^1.P}$.

To obtain the development of the portion below the section line **EF**, consider the face ①(elevation).

EA is part of **PA** and $\mathbf{E^2A^2}$ is its true length.

With centre $\mathbf{E^2}$ and radius $\mathbf{EF^1}$ (true length of **EF**), describe an arc cutting $\mathbf{PB^1}$ in **F**.

Join $\mathbf{E^2F}$.

With centre **F** and radius **FG** (plan), describe an arc cutting $\mathbf{PC^1}$ in **G**. Join **FG**.

With centre **G** and radius $\mathbf{EF^1}$ (true length of **HG**), describe an arc cutting $\mathbf{PD^1}$ in **H**.

Join **GH**.

With centre **H** and radius **EH** (plan), describe an arc cutting $\mathbf{PA^1}$ in **E**. Join **HE**.

Add the surface of the section on **EF** (Fig. 263) by first obtaining the true shape of the section (Fig. 264).

The surface development of the portion of the pyramid below **EF** is that portion within the "dotted" area.

The four lateral faces of the pyramid below **EH** *are shown* ① - - ④(*Fig.* **265**), *and may be drawn separately by finding the true lengths of the four lines forming the perimeter, and that of one diagonal in each case In face* ①**AB** *should equal* **3″** *and* $\mathbf{AE = A^2E^2}$; $\mathbf{EB = EB^1}$, $\mathbf{EF = EF^1}$ *and* $\mathbf{FB = F^2B^2}$.

This shape is similar to ①*in the development.*

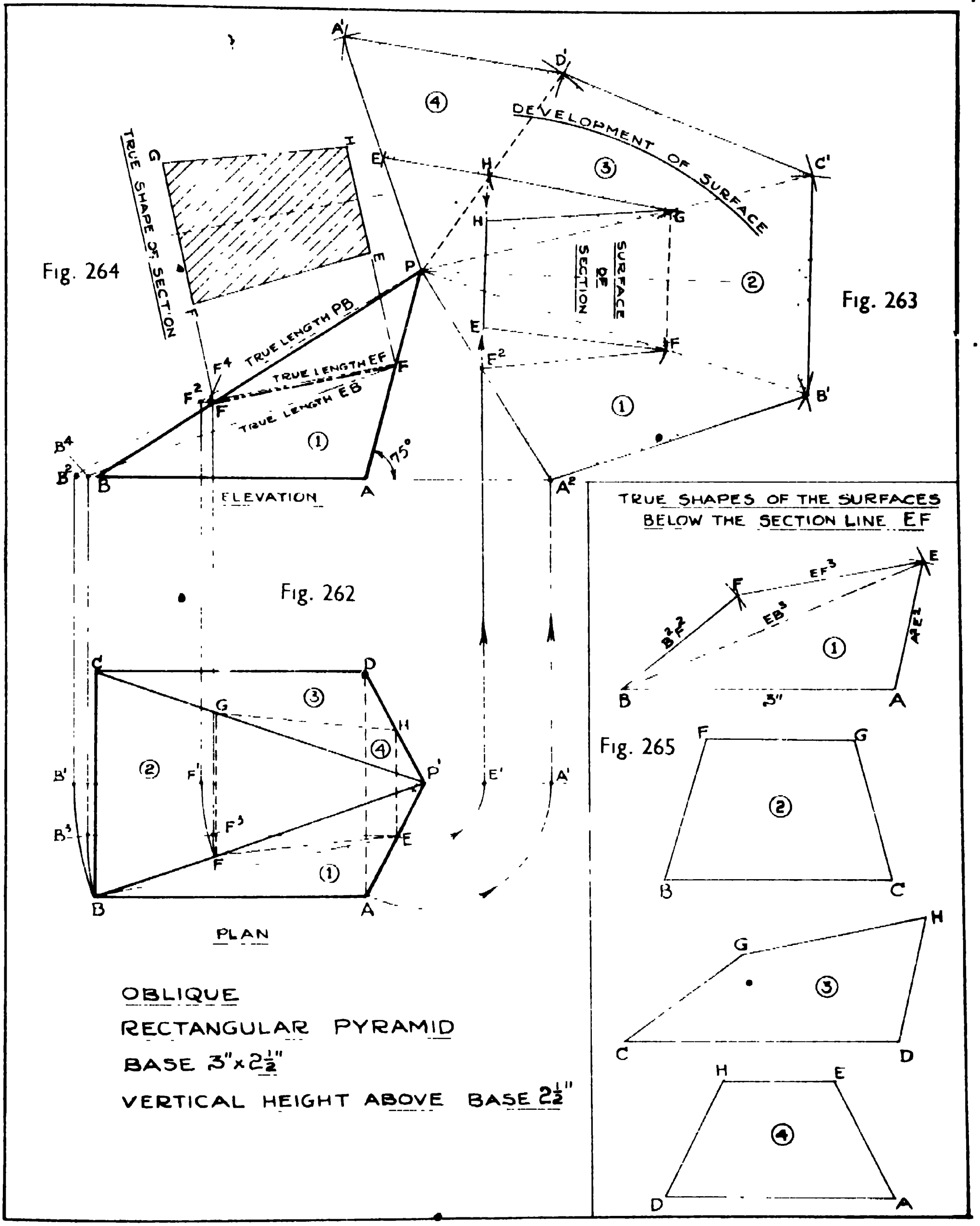


Fig. 264
TRUE SHAPE OF SECTION
DEVELOPMENT OF SURFACE
SURFACE OF SECTION
Fig. 263
TRUE LENGTH PB
TRUE LENGTH EF
TRUE LENGTH EB
75°
ELEVATION
Fig. 262
PLAN
TRUE SHAPES OF THE SURFACES BELOW THE SECTION LINE EF
3"
Fig. 265
OBLIQUE
RECTANGULAR PYRAMID
BASE 3"x2½"
VERTICAL HEIGHT ABOVE BASE 2½"

OBLIQUE SQUARE PYRAMID

EXERCISE 60 — Use half 22″ × 15″ paper — **PLATE 72**

Fig. 266 shows the plan and elevation of an oblique square pyramid cut by a horizontal plane CB. Draw the surface development of the pyramid and of the portion below BC. The apex A of the pyramid is "off-set," and A^{1} does not lie on the centre line through the base.

The edges of the pyramid are inclined to both planes so it is necessary to find their true lengths. Consider the edge **A2**.

With centre **A**^{1} (plan) and radius **A**^{1}**2** draw an arc meeting the horizontal line through **A**^{1} in **2**^{1} and continue vertically to meet the base line in **2**^{2} (elevation).

Join **A2**^{2} for the true length of **A2**.

True lengths of the other edges are obtained by the same method and are shown **A3**^{2}, **A4**^{2} and **A1**^{2}.

The complete development of the four faces can be drawn, commencing with **A1**^{2}.

With centre **A** and radius **A2**^{2} describe a long arc, and with centre **1**^{2} and radius **3**″ (side of base), cut the arc in point **2**.

Join **1**^{2}**.2**.

With centre **A** and radius **A3**^{2} describe a long arc, and with centre **2** and radius **3**″ (side of base), cut the arc in point **3**.

Join **2.3**.

The points **4** and **1** are obtained by similar methods to give the complete surface development of the pyramid **A.1**^{2}**.2.3.4.1.A**.

Draw a line through **C** parallel to **2.1**^{2} (elevation) cutting the four radial lines from **A** in **7**^{1}**.6**^{1}**.8**^{1}**.5**^{1}.

Point **6** lies on **A2** at the position where the arc drawn with centre A and a radius of **A6**^{1}, meets **A2** in **6**. Join **5**^{1}**6**.

Points **7**, **8** and **5** are obtained by the same method to give the surface development of that portion of the pyramid below **BC** as shown within the "dotted" area.

The four lateral surfaces of the pyramid below **BC**, **1** - - **4** (*plan*, *Fig.* 266) *may be drawn separately by finding the true lengths of the four lines forming the perimeter and that of one diagonal in each case* (*Fig.* **267**).

In face **1** **1-2** *should equal* 2″; **2.6** = **6**^{1}**2**^{2}; *diagonal* **6.1** = **6.1**^{1} (*elevation*); **6.5** = **6.5** (*plan*); **5.1** = **5**^{1}**.1**^{2}. *The shape is similar to* **1** *in the development.*

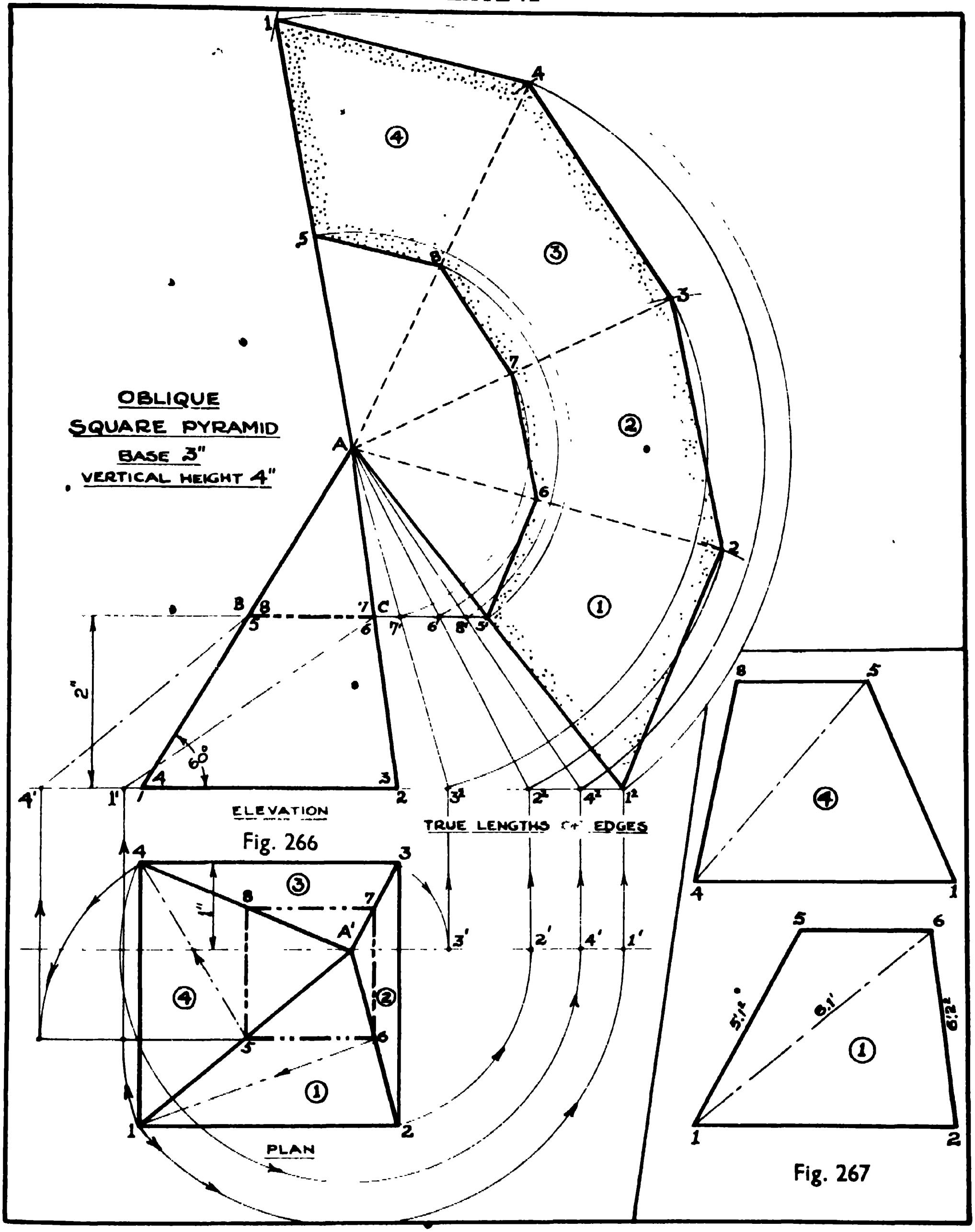


Fig. 266

Fig. 267

EXERCISE 61 — Use 22″ × 15″ paper — PLATE 73

Fig. 268 shows the plan and elevation of a sheet metal hopper. Draw, to a scale of 1″ to a foot, the given views and add:—

(a) Separate drawings for each of the four sloping sides.

(b) The complete surface development (Fig. 269).

(c) The construction to obtain the actual distance (in feet) from A to B.

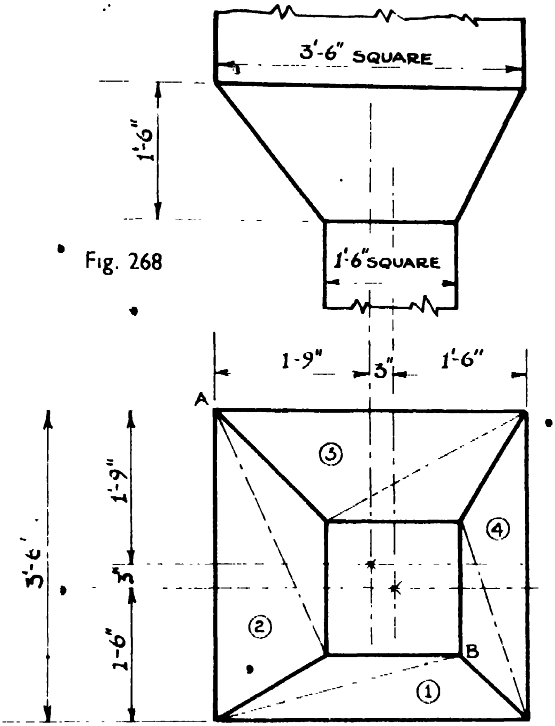


Fig. 268

TRUE SHAPE OF EACH OF THE FOUR SLOPING SIDES OF THE HOPPER HERE

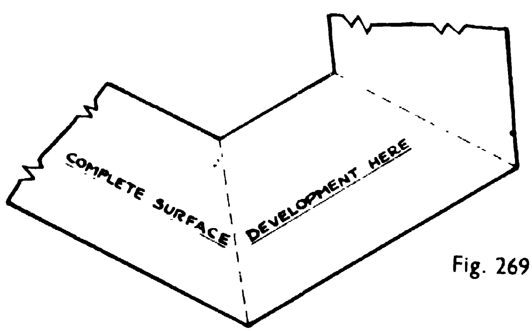


Fig. 269

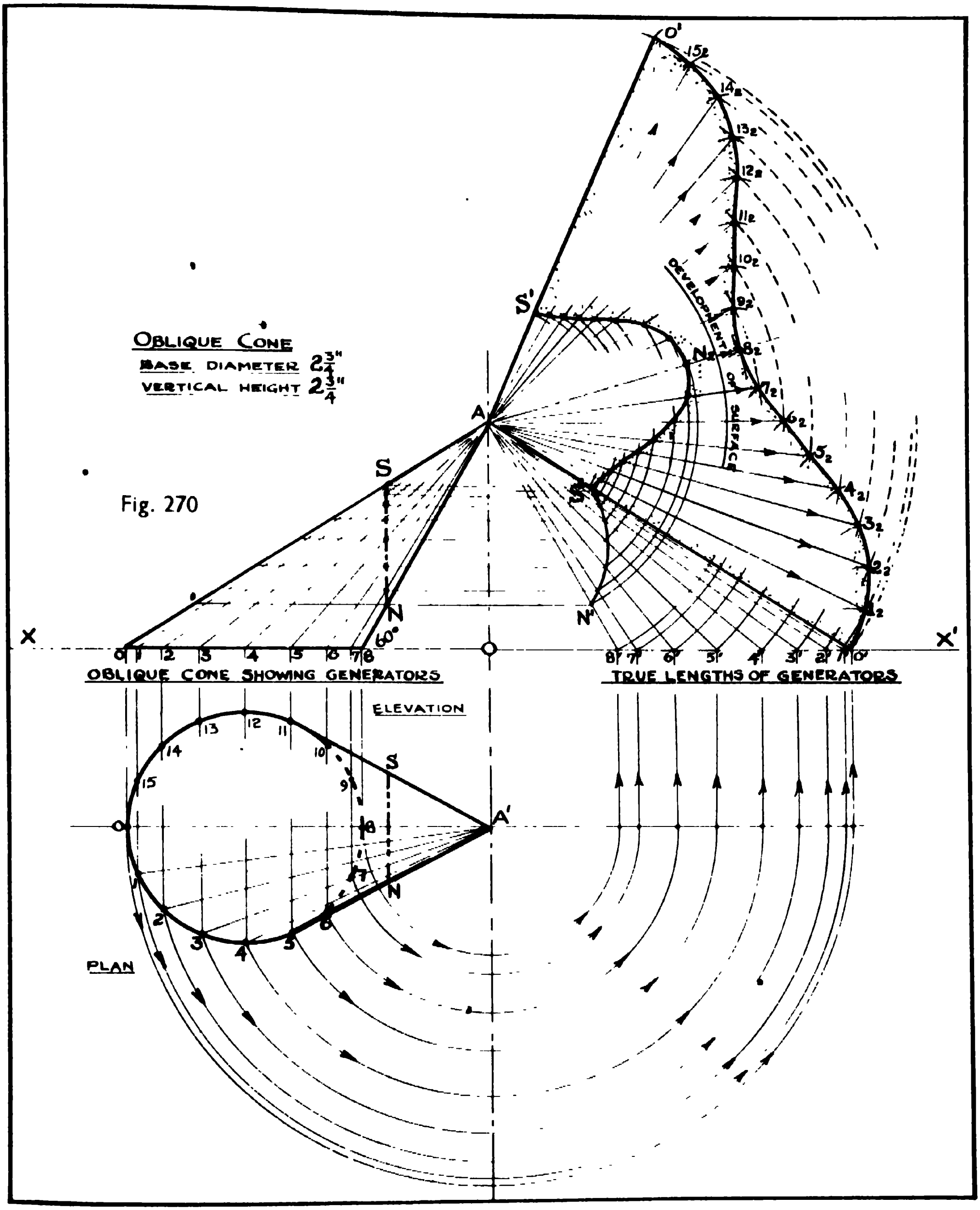
OBLIQUE CONE

EXERCISE 62 — Use half 22″ × 15″ paper — **PLATE 74**

Fig. 270 shows the elevation of an oblique cone cut by a vertical plane S-N. Draw the surface development of the cone and of the portion to the left of S-N.

Divide half the base circle into any number of equal parts, say 8, shown **0.1 - - - 7.8.**
Project these points upwards to meet the base line of the cone and join them to the apex A. These generators divide the surface into a number of elements which approximate, in shape, to triangles.
Join the points to **A**^{1} (plan) to obtain plans of the generators.
With centre **A**^{1} transfer the points, as shown, to obtain **8**^{1}**.7**^{1} **- - - 1**^{1}**.0**^{1} on **OX**^{1}.
Join **A8**^{1}, **A7**^{1} - - - **A1**^{1}, **A0**^{1} giving the true lengths of the generators.
Commence the development with **A0**^{1}.
With centre **A** and radius **A1**^{1} draw a short arc, and with centre **0**^{1} and radius **01** (plan), cut the arc in **1**$_2$.
With centre **A** and radius **A2**^{1} draw a short arc, and with centre **1**$_2$ and radius **1.2** (plan), cut the arc in **2**$_2$.
Continue in the same way with each radial to **8**$_2$ and draw a smooth curve through the points **0**^{1}**.1**$_2$ - - - **7**$_2$**8**$_2$. The second half of the curve will be similar.
The complete development is **A0**^{1}**1**$_2$**2**$_2$ - - - **15**$_2$**0**^{1}**A.**

The trace of section **S-N** cuts the generators (elevation), and the true lengths between the apex **A** and **S-N** are found by projecting the points of intersection to corresponding positions (shown between **S**^{1}**-N**^{1}) on the "true lengths" diagram.
With centre A transfer the points on **S**^{1}**N**^{1} to their corresponding elements in the development to obtain the curve **S**^{1}**N**$_2$**S**^{1}.
The surface development of the portion to the left of **S-N** lies within the "dotted" area.


OBLIQUE CONE
BASE DIAMETER 2 3/4"
VERTICAL HEIGHT 2 3/4"
Fig. 270
OBLIQUE CONE SHOWING GENERATORS
ELEVATION
PLAN
TRUE LENGTHS OF GENERATORS
DEVELOPMENT OF SURFACE

EXERCISE 63 — Use 22″ × 15″ paper — PLATE 75

Much of the detail construction work, described in the previous Exercise 62, can now be omitted by using the principles involved in a direct method within the elevation of the cone.

Fig. 271 shows the same oblique cone.

Describe a semi-circle on the base, and divide it into any number of equal parts, say 6, as shown **0.1.** - - - **5.6.**
Drop a perpendicular from **A** to meet the base line produced in **X**.
With centre **X** transfer the points to the base of the cone in **1^{1}2^1** - - - **5^1**.
Join **A1^1**, **A2^1** - - - **A5^1** giving the true lengths of these generators.
With centre A and radii **A0, A1^1 A2^1** - - - **A5^1, A6,** draw a series of arcs.
Set the dividers to the distance between any of the small arcs, say **0-1**, in the semi-circle (plan), and commencing at **0**, prick off the point **1$_2$** on this radial in the development.
Continue by using **1$_2$** as centre, and the same distance on the dividers, prick off the point **2$_2$**. Continue on each radial until the point **6$_2$** is reached.
Draw a smooth curve through the points **0,1$_2$,2$_2$** - - - **6$_2$**.
The other half of the curve is obtained by using the same numbering and radials in reverse order.
Join the points **0.1$_2$.2$_2$** - - - **0$_2$** with a smooth curve.
The complete development is **A01$_2$2$_2$3$_2$** - - - **0$_2$A**.

To obtain the outline of the development of the section to the left of **S-N**, join **A1^{1}A2^1** - - - **A^6** on the base of the cone to give the true lengths of the generators. This construction is now shown on the face of the cone.
Mark the points where the trace of **S-N** cuts the generators.
With centre **A** and radii to these points of intersection, describe arcs to meet the radials **A1$_2$A2$_2$** - - - **0$_2$**.
Join these points with a smooth curve between **SN$_2$S$_2$**.
The surface development of the portion to the left of **S-N** lies within the dotted area.

Fig. 272 shows the junction piece (1) between two cylinders.

Draw, to a scale of 1″ to a foot, the development of the junction piece in the position shown.

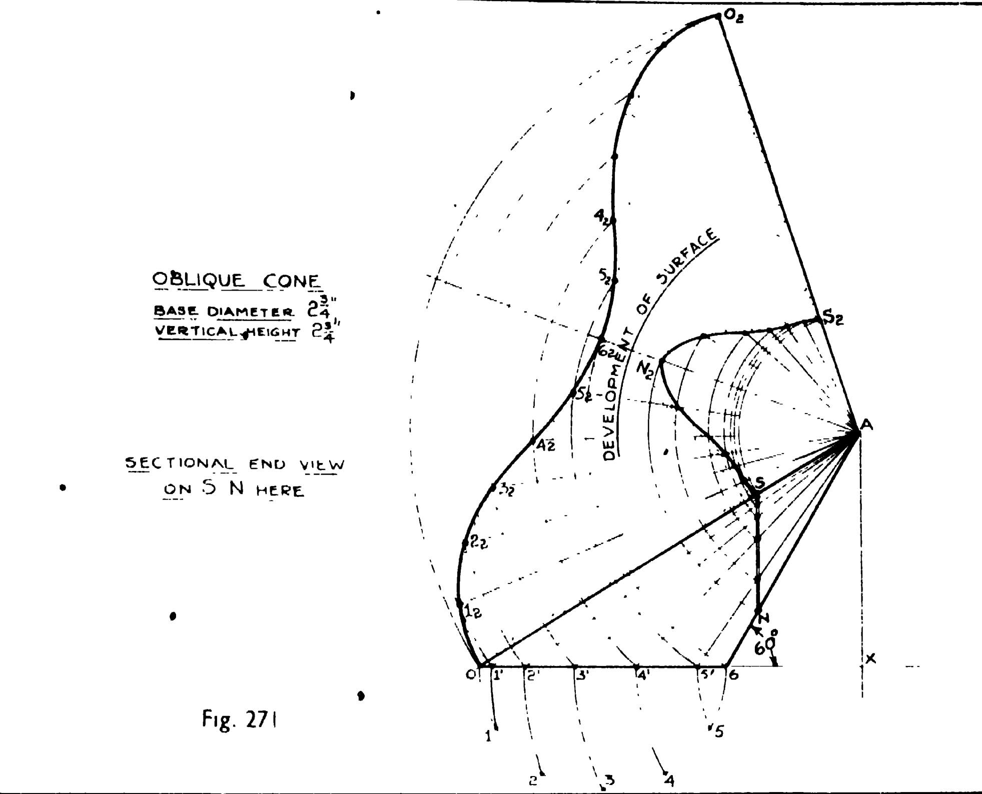


Fig. 271

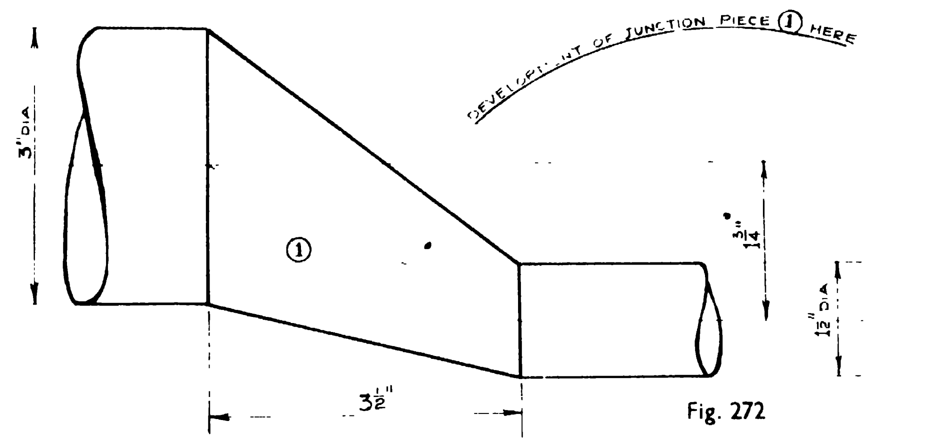


Fig. 272

TRANSITION PIECES

An important training in the shaping of sheetmetal work is the ability to develop the surfaces of pieces which may be required to link up, or "*fill in*," between two "*off-set*" openings of similar or different shapes. Such pieces are aptly described as "transition" pieces. In the case of curved surfaces it may not be possible to make an exact development, and an approximate method known as the "triangulation method" is employed. It consists of dividing the curved surface into a series of triangles which, when pieced together, approximate to the required development. This problem arises when connecting up pipes, ventilators, chutes, canopies, etc.

EXERCISE 64 — Use 22" × 15" paper — PLATE 76

Fig. 273 shows the plan and elevation of a chute, consisting of a square opening leading into a circular opening.

Divide the semi-circle (plan) into any number of equal parts, say 8, and project them to the elevation.

Join **1.2.3.4. to A** and **4.5.6.7 to B** in both plan and elevation, and find the true lengths of these radials at **A0**^{1}, **A1**^{1} - - - **A4**^{1} and **B.4**^{1}, **B5**^{1} - - - **B8**^{1}.

Note: A more convenient method of obtaining the true lengths is to prepare a separate drawing as follows:—

In the elevation, drop perpendiculars from **A** and **B** to the base line produced in the points **X** and **Y**.

In **Fig. 274** the vertical line **AX** = **AX** (elevation) and **ZXY** is drawn horizontal to it.

To the left of **X** set off **A0, A1,** - - - **A4** (plan of radials from **A** to points on the cylinder — Fig. 273).

To the right of **X** set off **B4, B5,**- - - **B8** (plan of similar radials from **B**).

Join up the points obtained on **XZ** and **XY** to **A** for the true lengths of the radials from corners **A** and **B** respectively.

Commence development (Fig. 275) by making **BB**^{1} = **BF** = **2**" (half side of square).

With centre **B** and radius **B8** (elevation), describe an arc, and with centre **B**^{1} and radius **B8**^{1} (elevation or **B**^{8} selected from **Fig. 274**), cut the arc in **8**^{1}

Continue with **8**^{1} as centre and radius equal to any of the arcs, say **87** on the semi-circle (plan), describe an arc, and with centre **B**^{1} and radius **B7**^{1} (or **B7** selected from **Fig. 274**), cut the arc in the point **7**^{1}.

Proceed in the same manner for all the radials from corner **B**. to obtain the curve between **8**^{1} and **4**^{1}.

B^1**A** = **BA** = **4**" (side of square).

With centre **B**^{1} and radius **BA** describe an arc, and with centre **4**^{1} and radius **A4**^{1} (elevation or **A**^{4} selected from **Fig. 274**), cut the arc to fix the corner point **A**.

Continue with **4**^{1} as centre and radius equal to any of the arcs, say **43**, on the semi-circle (plan), describe an arc, and with centre **B** and radius **A3**^{1} (or **A**^{3} selected from **Fig. 274**) cut the arc in **3**^{1}.

Proceed in the same manner for all radials from corner **A** to obtain the curve between **4**^{1} and **0**^{1}.

Complete the development by obtaining the other half of the curve as shown in **Fig. 275**.

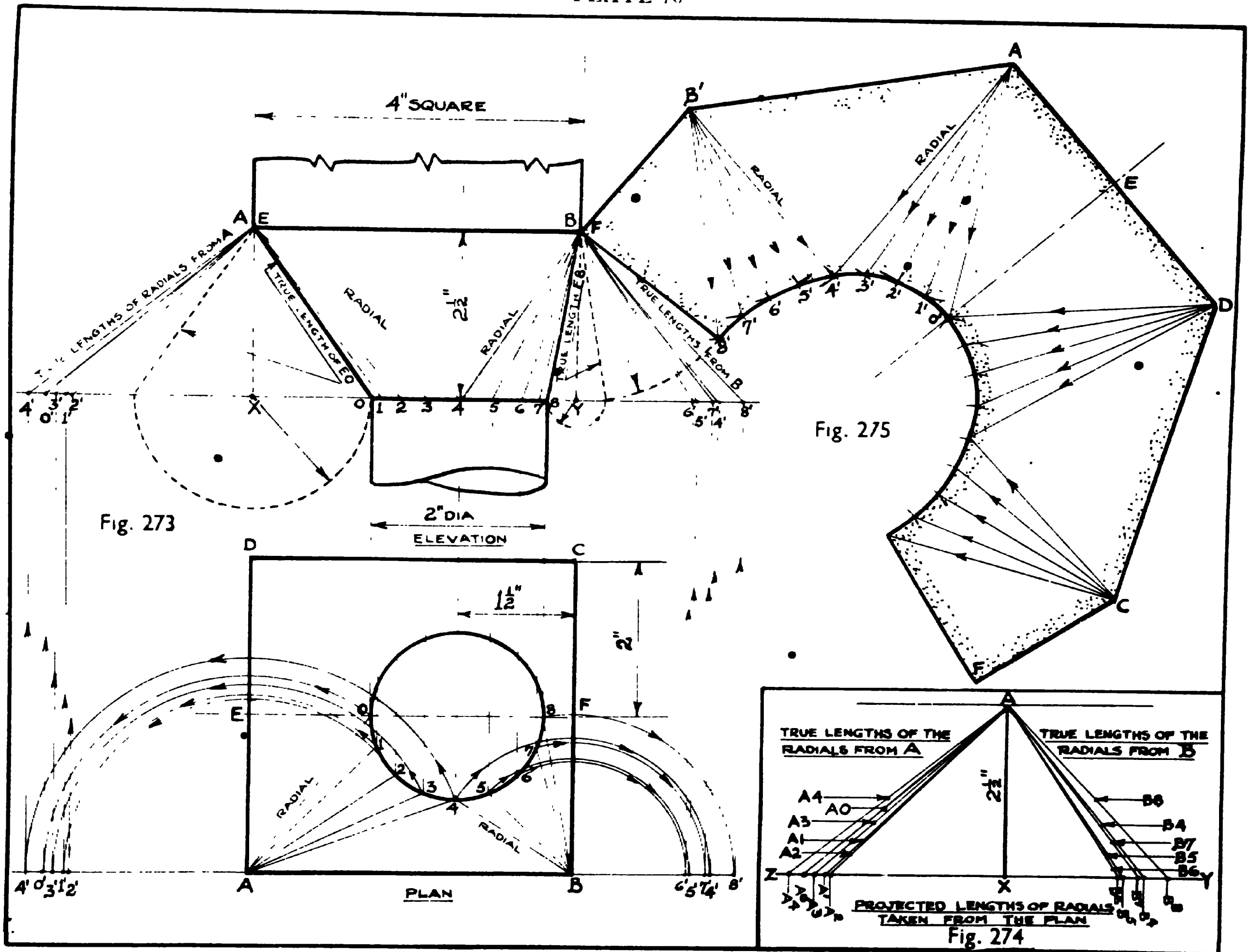


Fig. 273

Fig. 275

Fig. 274

EXERCISE 65 — Use 22" × 15" paper — PLATE 77

Fig. 276 shows the plan and elevation of a ventilator consisting of two cylindrical funnels, of different diameters, joined by a transition piece in the shape of the frustum of an oblique cone. Draw, to a scale of 1" to a foot, the development of the transition piece between the funnels.

The construction for this problem is most conveniently done by the method described in the previous Exercise 64, and is shown in diagram form (**Fig. 277**).

Divide the semi-circles (plan) into any number of equal parts, say 8, and join them together to represent plans of generators (or radials), e.g., **0A, 1B, 2C** - - - **7H, 8J**.

Draw a diagonal through each as shown **0B, 1C, 2D** - - - **6H, 7J**.

The surface has now been divided into a series of approximate triangular shaped elements.

The generators and the diagonals are inclined to both planes so it is necessary to find their true lengths.

The true length of the generator element **C2** is equal to the hypotenuse of a right angled triangle (**Fig. 278**), whose vertical height is the distance (2′ 6″) between the lines of joints (**08-aj**) and base equal to **C2** (plan).

The true length of the diagonal **D2** is found by the same method.

This construction for all generators and all diagonals is conveniently arranged in the diagram **Fig. 277** prepared as follows:

XY = vertical height 2′ 6″.

On the base line, and to the right of **Y**, set off the lengths of the generators, taken from the plan, making **Y-J⁸ = J8 ; Y-H⁷ = H7 ;** - - - **Y-B¹ = B1 ; Y-Aᶜ = A0.**

Join these points to **X** to obtain the true lengths of the generators.

By similar methods, and to the left of **Y**, obtain the true lengths of the diagonals.

Commence the development (**Fig. 279**) by making **J8 = XJ8** (or **j8, Fig. 276**).

With centre **J** and radius **XJ⁷** describe an arc, and with centre **8** and radius equal any of the small arcs (say **87**) on the plan semi-circle, cut the arc in point **7**.

With centre **J** and radius equal to any of the larger arcs (say **JH**) on the plan semi-circle, describe an arc, and with centre **7** and radius **XH⁷** cut the arc in point **H**.

Draw arc **H6** with radius equal to **XH⁶** and cut the arc with a radius of **76** (plan).

Continue in the same way, taking diagonal and generator alternately, until **0A** is reached.

Join all the points with a smooth curve to give half the development.

The other half is similar and may be obtained by the same methods or by using tracing paper.

The complete development of the transition piece is shown within the dotted area.

PLATE 77

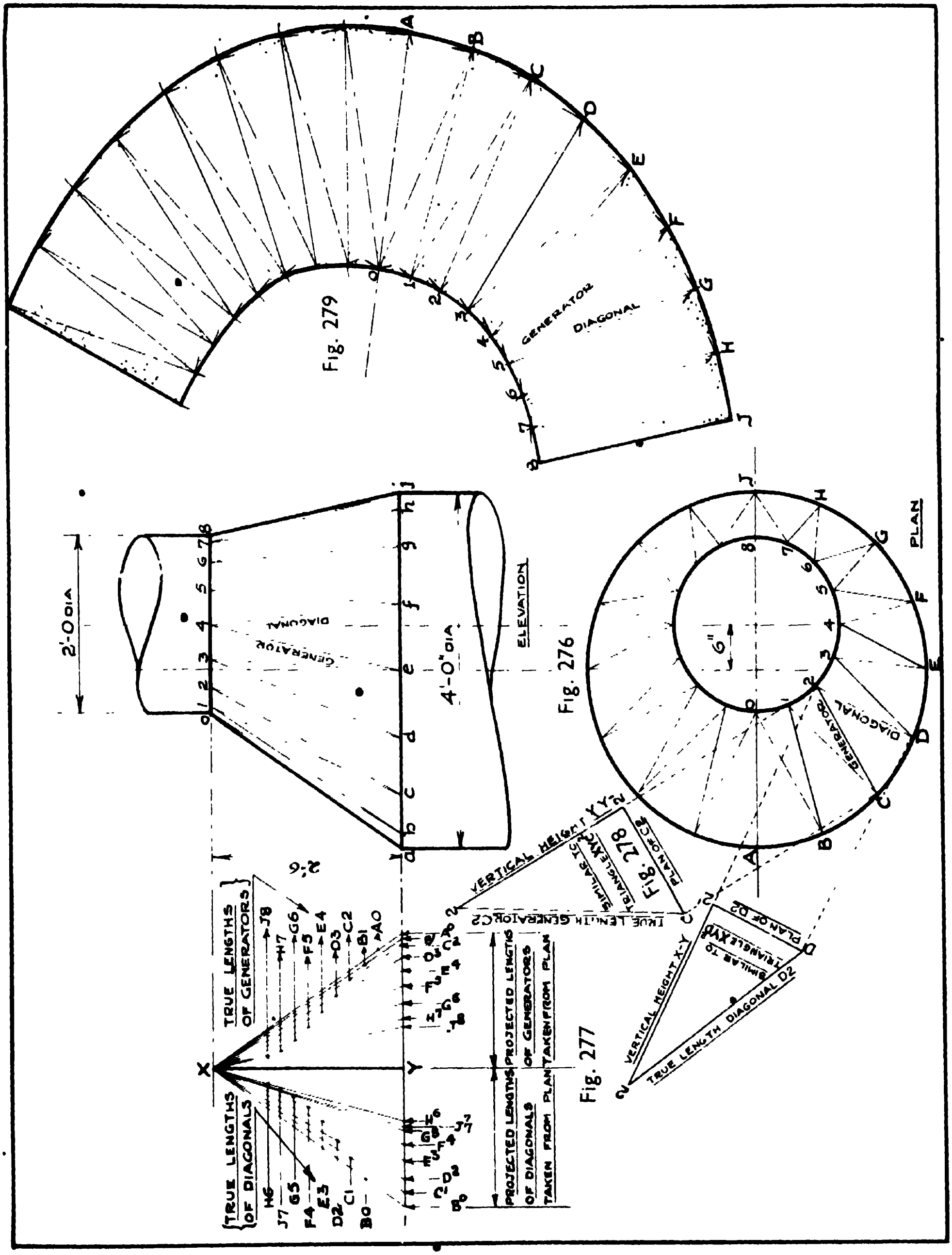


Fig. 279
GENERATOR
DIAGONAL
2'-0" DIA
4'-0" DIA
2'6"
ELEVATION
Fig. 276
PLAN
6"
Fig. 278
VERTICAL HEIGHT YY2
TRUE LENGTH GENERATOR C2
PLAN OF C2
SIMILAR TO TRIANGLE XYC
VERTICAL HEIGHT X-Y
TRUE LENGTH DIAGONAL D2
PLAN OF D2
SIMILAR TO TRIANGLE XYD
Fig. 277
TRUE LENGTHS OF GENERATORS
TRUE LENGTHS OF DIAGONALS
PROJECTED LENGTHS OF GENERATORS TAKEN FROM PLAN
PROJECTED LENGTHS OF DIAGONALS TAKEN FROM PLAN

CHAPTER 9

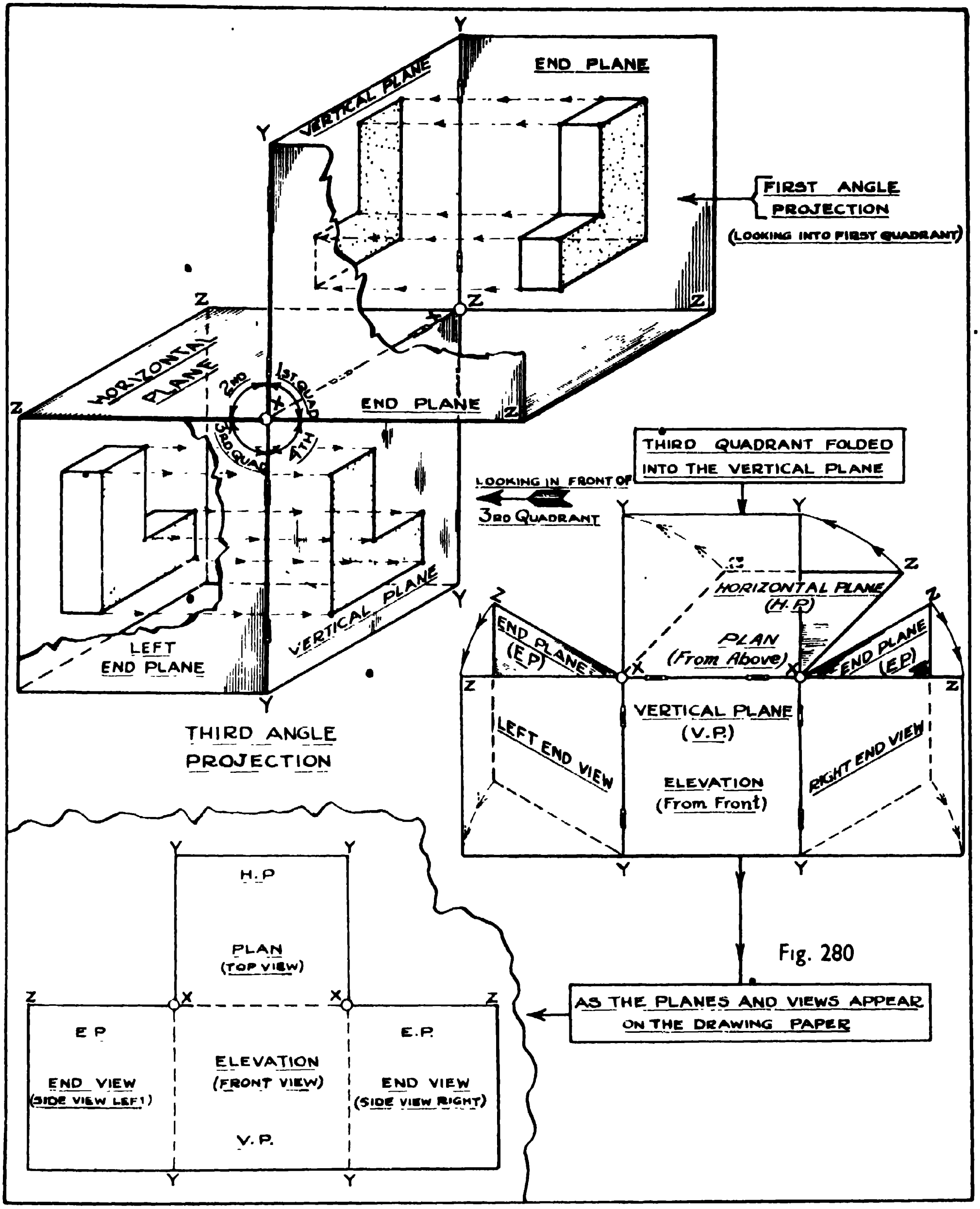
THIRD ANGLE (OR AMERICAN) PROJECTION — INKING-IN DRAWINGS AND TRACINGS — DUPLICATION OF DRAWINGS — CO-ORDINATE DRAWING — ASSEMBLY EXERCISES — MENSURATION OF PLANE FIGURES

Projection is generally carried out in the First or Third Quadrant (Plate 78) and referred to as **FIRST** and **THIRD ANGLE PROJECTION** respectively. First Angle Projection (described in Chapter 5, Part I) has been used so far, since it is the method adopted in Britain. In modern times, there is an ever increasing international link-up, not only among industrial concerns having mutual interests, but also in the Services and in Government Departments concerned with scientific and technical developments. It is therefore desirable to have a knowledge of Third Angle Projection as generally practised in North America and by many British firms. The British Standards Publication, "Engineering Drawing Practice," states that both systems are acceptable as British Standards, and it is possible that, sometime in the future one or other, or perhaps a combination of both, may become universal. It is important that the pupil should acquaint himself with the fundamental principles upon which each system is based, viz.,

FIRST ANGLE PROJECTION: The object is regarded as being in *front of the VP* and projection is backwards from the object to the VP (elevation) and downwards to the HP (plan), thus showing the elevation directly above its plan. The views on the planes are full size "shadows" of the object.

THIRD ANGLE PROJECTION: The object is regarded as being *behind the VP*, and projection is from the object towards the VP (elevation) and upwards towards HP (plan), thus showing the plan above its elevation (Fig. 280). The views on the planes are full size "reflections" of the object.

In both systems, the VP is very important, since it is always considered to be in front of the viewer, and is represented by the surface of the drawing paper (Plate 78).



END PLANE
VERTICAL PLANE
FIRST ANGLE PROJECTION
(LOOKING INTO FIRST QUADRANT)
HORIZONTAL PLANE
END PLANE
2ND
1ST QUAD
3RD QUAD
4TH
LEFT END PLANE
VERTICAL PLANE
THIRD ANGLE PROJECTION
THIRD QUADRANT FOLDED INTO THE VERTICAL PLANE
LOOKING IN FRONT OF 3RD QUADRANT
HORIZONTAL PLANE (H.P)
PLAN (From Above)
END PLANE (E.P)
END PLANE (E.P)
VERTICAL PLANE (V.P)
LEFT END VIEW
ELEVATION (From Front)
RIGHT END VIEW
H.P
PLAN (TOP VIEW)
E.P
END VIEW (SIDE VIEW LEFT)
ELEVATION (FRONT VIEW)
V.P.
E.P
END VIEW (SIDE VIEW RIGHT)
AS THE PLANES AND VIEWS APPEAR ON THE DRAWING PAPER

Fig. 280

THIRD ANGLE PROJECTION PLATE 79

Fig. 281 shows the Third Quadrant in the form of a box. The sides are assumed to be transparent and to represent the principal planes of projection. An object, shape **L**, is placed within the box and viewed by an observer in front of the VP. The corners of the object are projected (or reflected) forward towards the VP to obtain the elevation (dotted surface), upwards towards the HP to obtain the plan (broken line shading), and outwards towards the EPs to obtain end (or side) views. It must be noted that the end views are those of the object adjacent to their planes of projection.

The three planes, HP and two EPs, are now each turned through a right angle, upwards and outwards respectively, into the VP. The views so obtained are shown in Fig. 282. Study this mental procedure carefully by tracing the points to their corresponding positions in the four views.

Fig. 283 below shows a comparison between the views of the object as obtained by First and by Third Angle Projection.

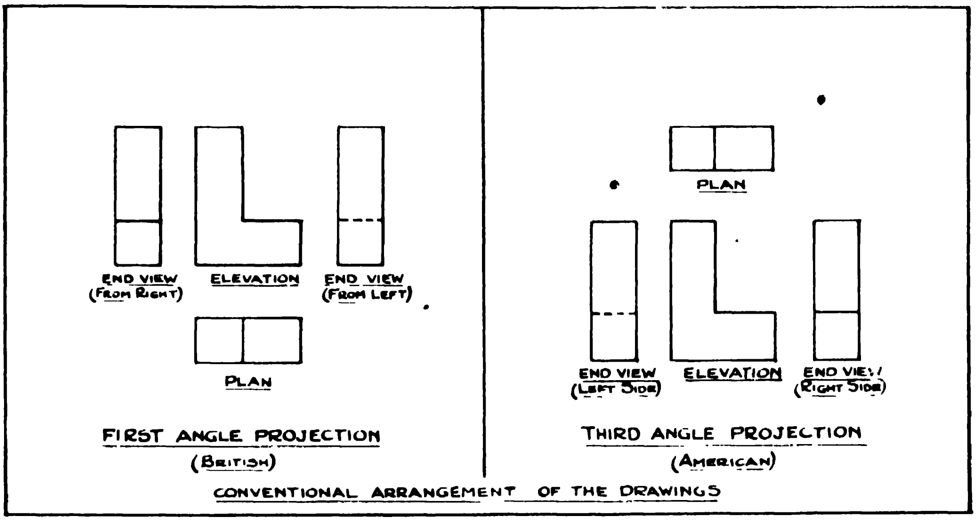


Fig. 283

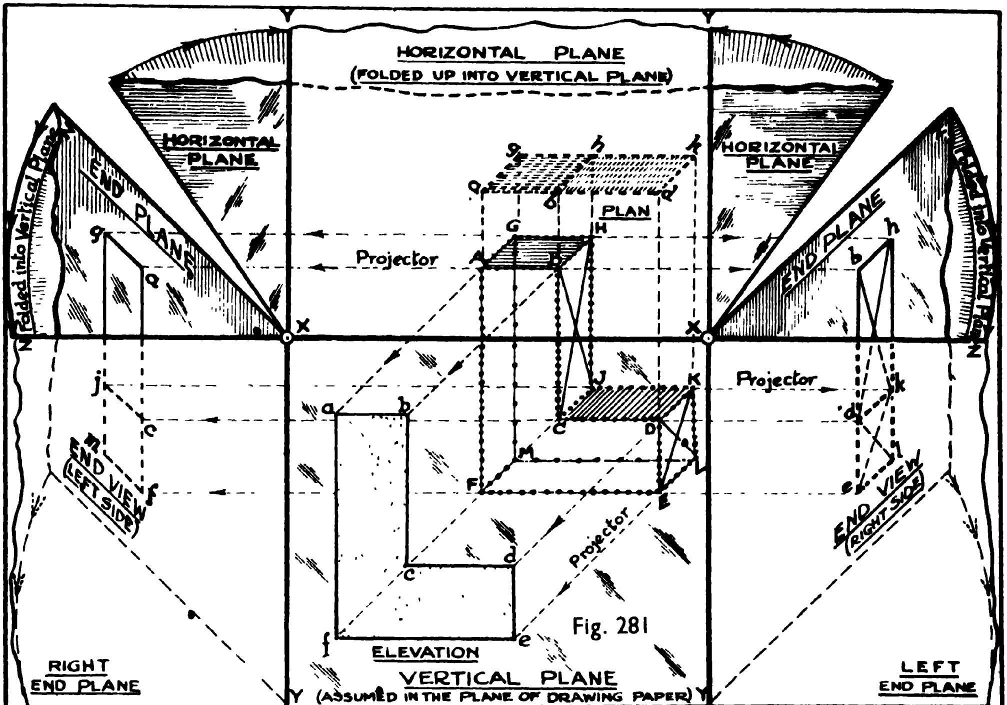
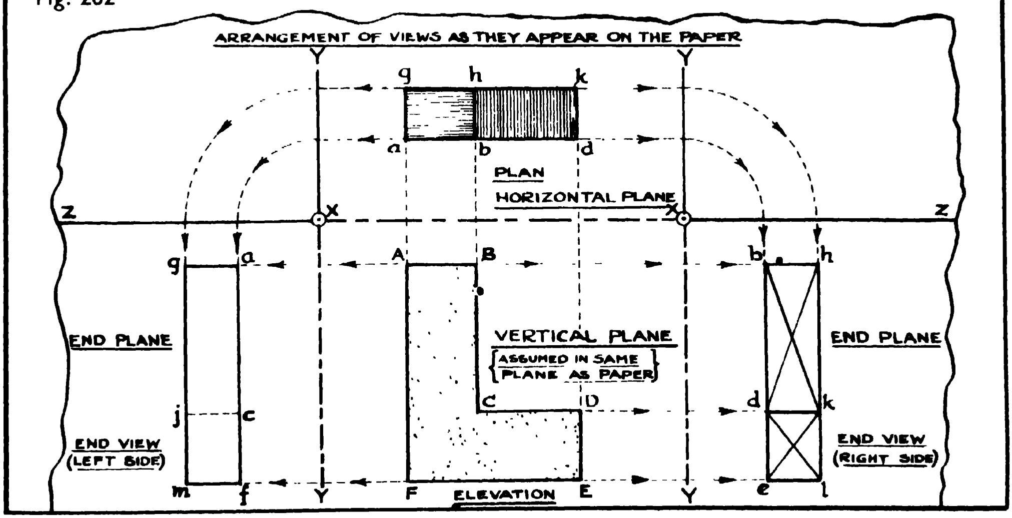


Fig. 281

THIRD ANGLE PROJECTION

Fig. 282



EXERCISE 66 — Use 22″ × 15″ paper — PLATE 80

(a) **Fig. 284** shows the dimensioned sketch of a curved angle block.

(b) **Fig. 285** shows the four conventional views drawn by First Angle Projection. Draw these views and insert all dimensions.

(c) **Fig. 286** shows same views drawn by Third Angle Projection. Draw these views, with the help of projectors, and insert all dimensions.

(d) **Fig. 287** shows the plan of the block in a new position. Add the three other views by Third Angle Projection. Name the views but omit dimensions.

(e) **Fig. 288** shows another elevation of the block. Add the three other views by Third Angle Projection. Name the views but omit dimensions.

PLATE 80

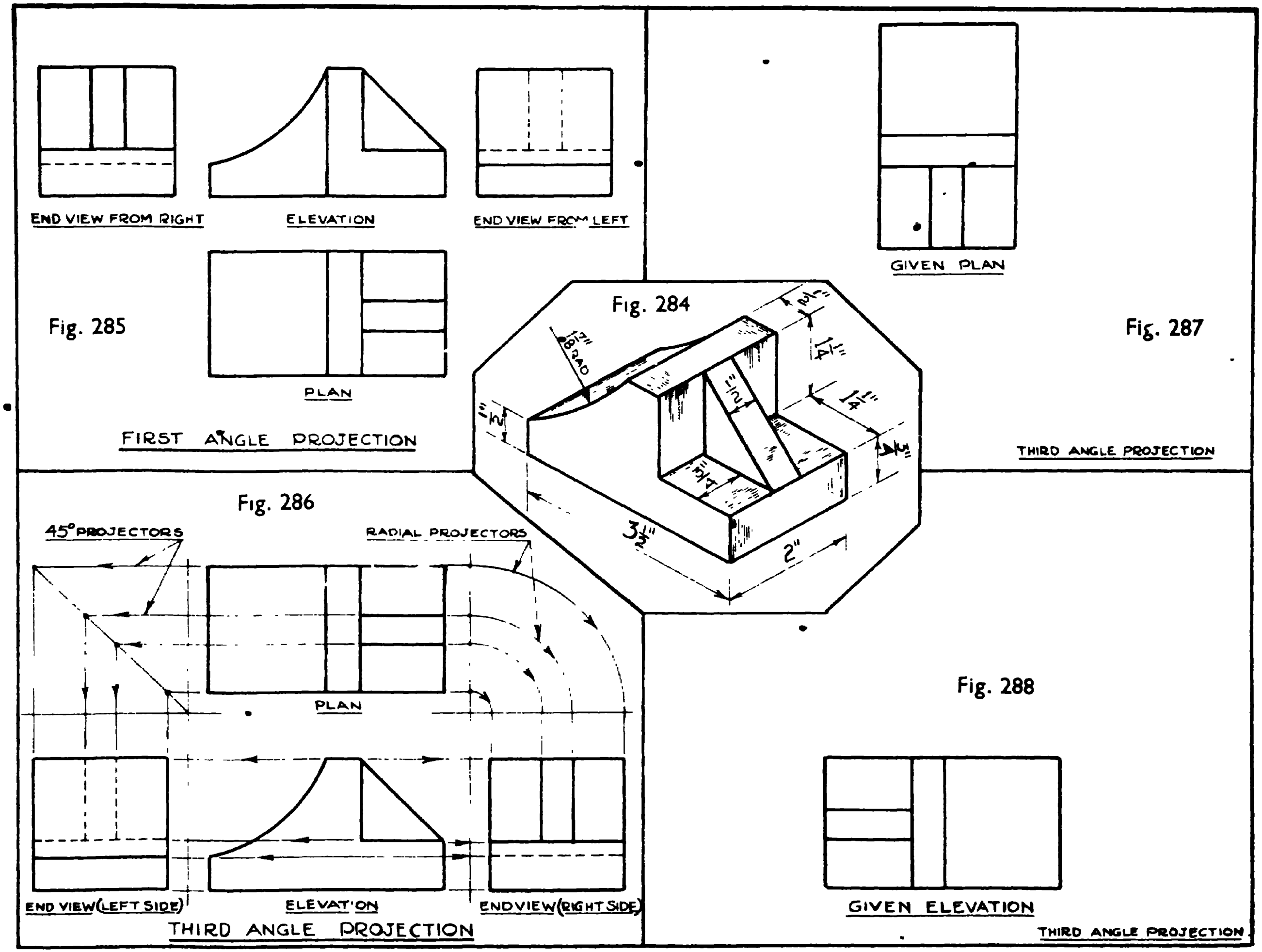


Fig. 284
$1\frac{7}{8}$" RAD
$\frac{1}{2}$"
$1\frac{1}{4}$"
$1\frac{1}{4}$"
$\frac{1}{2}$"
$\frac{3}{4}$"
$3\frac{1}{2}$"
2"
Fig. 285
END VIEW FROM RIGHT
ELEVATION
END VIEW FROM LEFT
PLAN
FIRST ANGLE PROJECTION
Fig. 286
45° PROJECTORS
RADIAL PROJECTORS
PLAN
END VIEW (LEFT SIDE)
ELEVATION
ENDVIEW (RIGHT SIDE)
THIRD ANGLE PROJECTION
Fig. 287
GIVEN PLAN
THIRD ANGLE PROJECTION
Fig. 288
GIVEN ELEVATION
THIRD ANGLE PROJECTION

EXERCISE 67 — Use 22″ × 15″ paper — **PLATE 81**

(a) **Fig. 289** shows the dimensioned sketch of a clamp.

Draw, to a scale of full size and by Third Angle Projection, the three other conventional views from the given elevation (Fig. 290).

(b) Draw, as for (a) above, the three other conventional views from the given plan (Fig. 291).

Do not use projectors, but show all hidden lines.

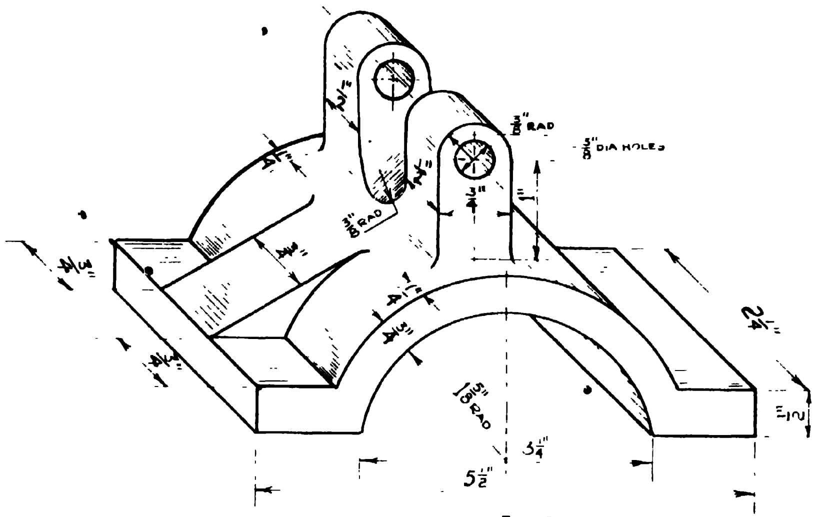


Fig. 289

10"

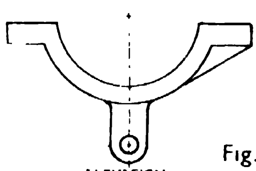
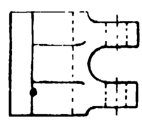


Fig. 290

ELEVATION

LAY OUT OF PAPER



PLAN

Fig. 291

THIRD ANGLE PROJECTION

EXERCISE 68 — Use 22" × 15" paper — PLATE 82

Fig. 292 shows the dimensioned sketch of a vee shaped casting.

End View placed alongside Plan

As in First Angle Projection, it is occasionally more convenient to show a side view alongside the plan. In Third Angle Projection this view is drawn by projection from the elevation, to obtain heights corresponding to points in the plan. This can be easily followed on Fig. 293.

Fig. 293. Copy the four given views and insert the dimensions.

Fig. 294 shows elevations of the block in two other positions. Draw the given elevation and add, without the use of projectors, the corresponding plan and two end views (including hidden lines in all views) in the normal positions for Third Angle Projection.

PLATE 82

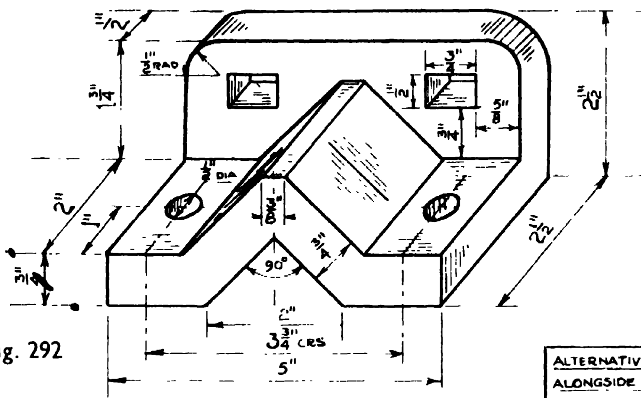


Fig. 292

ALTERNATIVE POSITION OF SIDE VIEW ALONGSIDE PLAN OBTAINED BY PROJECTION FROM ELEVATION

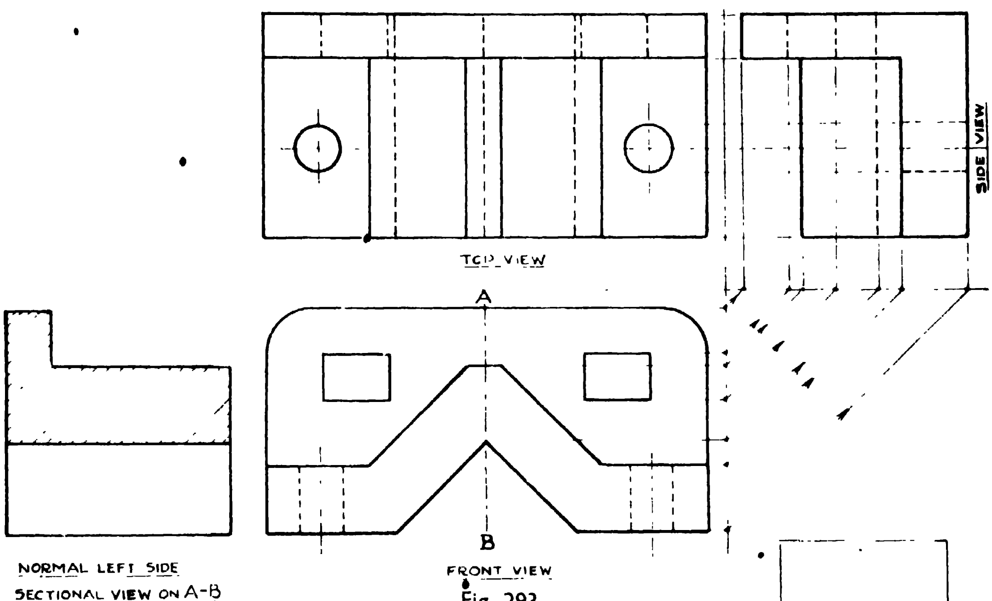


Fig. 293

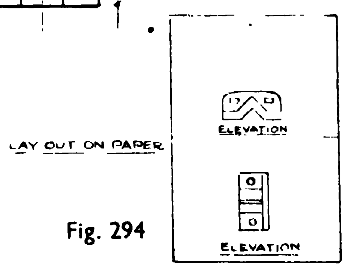


Fig. 294

THIRD ANGLE PROJECTION

EXERCISE 69 — Use 22″ × 15″ paper — PLATE 83

Fig. 295 shows the plan and elevation (drawn by First Angle Projection) of a ribbed casting.

Imagine that the casting has been turned over so that web is underneath and the hole for the shaft is on the right. Draw, by Third Angle Projection, the plan, elevation and left-side view. Insert hidden lines and dimensions.

Fig. 296 shows the half sectional elevation of a circular casting having four strengthening ribs with four holes midway between them.

Note: In the section the rib is shown in full although its actual position is $22\frac{1}{2}°$ further round the circumference since the section is taken through a hole. This is usual practice, in order to provide information, and the rib is not shaded as being in section (see page 29 Part 1).

Imagine the casting has been turned through 90° in an anti-clockwise direction when its axis will be parallel to **H.P.** Draw, by Third Angle Projection, a half sectional elevation and a complete view showing the left side.

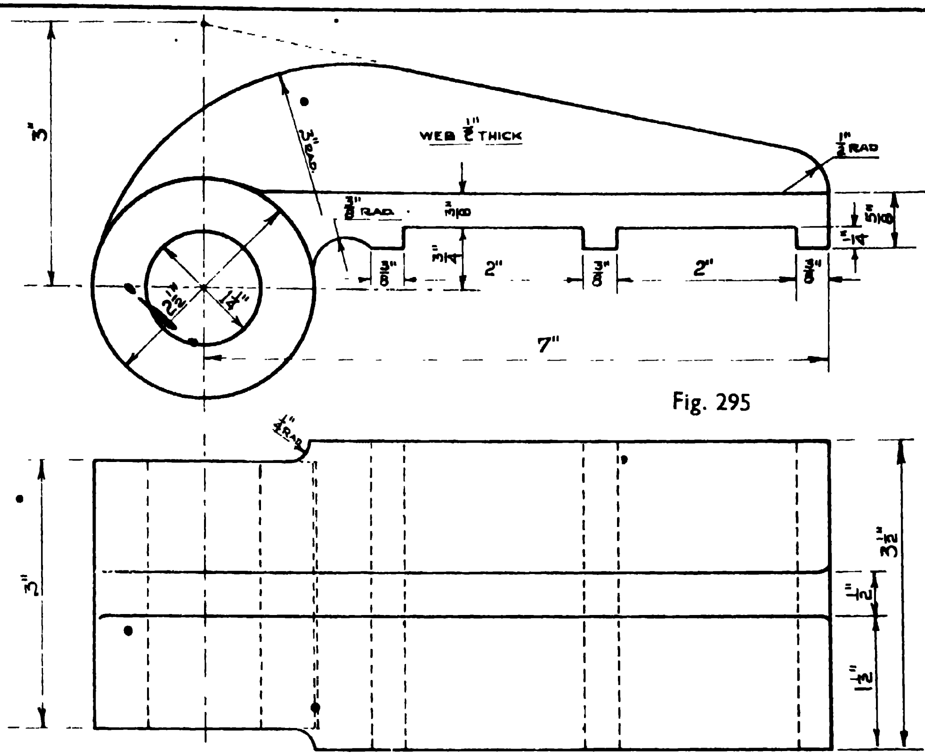


Fig. 295

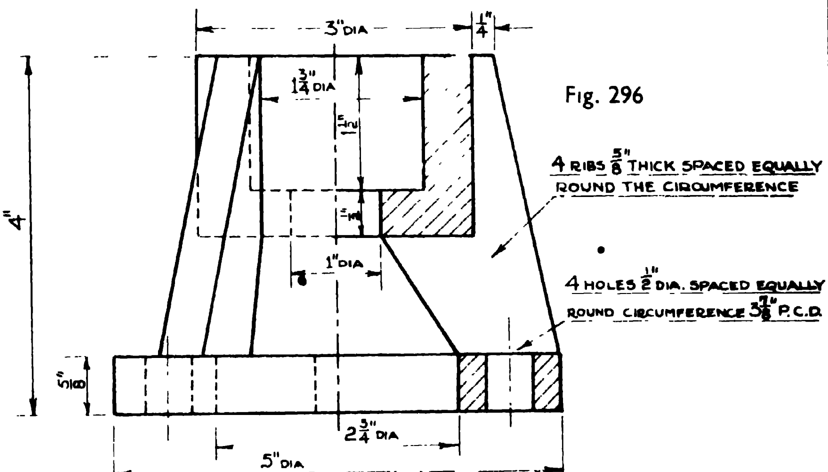


Fig. 296

INKING-IN A DRAWING

The pencil drawing is completely finished, including dimensions and title. Inking-in is the process of drawing over the pencil lines with black waterproof ink.

Draw (or Ruling) Pen: This pen is used for drawing straight lines with the aid of tee and or set squares, and should never be used for lettering or free-hand drawing. Fig. 297 shows a very popular type of pen. It is filled by inserting ink, to a depth of about $\frac{1}{4}''$, between the legs, with a special quill filling cork supplied with the ink bottle (Fig. 298).

The pen should never be filled in a vertical position, and certainly not over the drawing board, as there is always the risk of a drop of ink falling from the quill on to the drawing.

The desired thickness of line is obtained by turning the small thumb screw on the nib. Test the pen for use by trying it on the same kind of paper as that used for the drawing. It should not be tested on blotting paper or a hard surface. A clean sharp line is obtained when both points of the pen are in contact with the paper, and the pen is held in an almost vertical position with the thumb screw facing to the outside. A slight slope to the right gives a good view of the line being drawn. A light grip of the pen, without any downward pressure, gives the best results.

The nib should never be allowed to get between the tee square (or set square) and the drawing paper, as this is liable to smudge the line when the tee square is moved to a new position. The pen must be kept in a clean condition by opening up the legs and removing unused ink with a soft cloth. Should there be any dried ink adhering to the legs, it can be removed by rubbing with a piece of fine sand-paper or by special ink cleaner supplied for the purpose. The cork should be kept in the bottle when not in use to prevent the ink from drying up and becoming too thick for use in the pen.

It is important to go over the pencil line carefully and when a heavy line is required the pen should be used so that the thickness is distributed evenly on each side of the pencil line and not entirely above or below it.

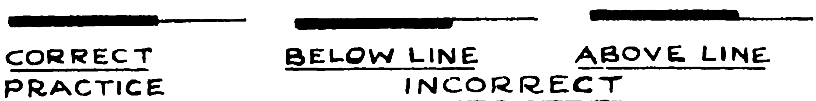


Fig. 299 (Pelican Graphos Pen) and Fig. 300 (Rapidograph Stylo Pen) are modern developments of the double nib pen. They are arranged so that the pen barrel contains a reservoir of ink similar to an ordinary fountain pen. Such pens can be used, and even laid aside, for long periods without refilling, and are convenient, easy to handle and efficient.

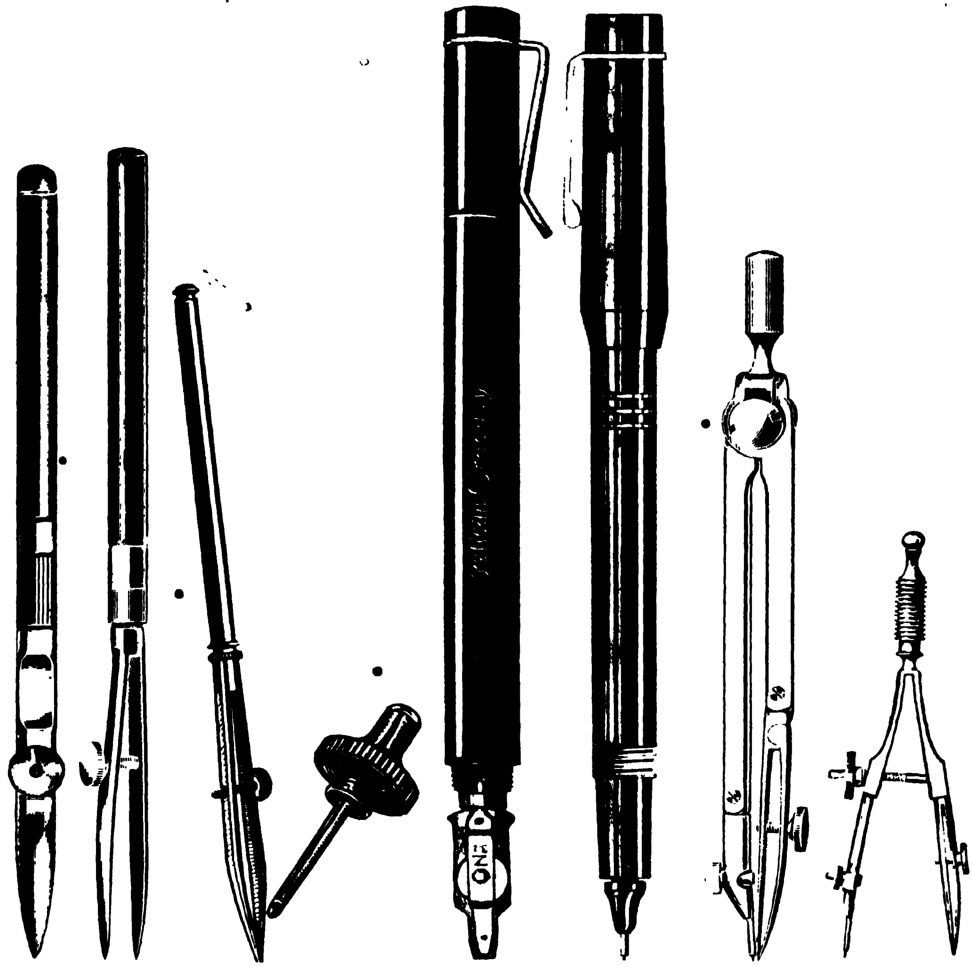


Fig. 297 Fig. 298 DOUBLE NIB DRAW OR RULING PEN

Fig. 299 PELICAN GRAPHOS

Fig. 300 RAPIDOGRAPH STYLO

Fig. 301. INK COMPASSES

Fig. 302 INK SPRING BOWS

Ink Compasses and Spring Bow Compasses (Figs. 301 and 302): These are used for drawing circles and arcs. The method of filling with ink is similar to that for the Draw Pen. **Spring Bows** are used for circles up to about 1" radius. When adjusting the Spring Bows, the two legs should be pressed together while turning the thumb screw, thus removing the pressure on it and preventing excessive wear on the fine thread.

ORDER OF INKING-IN A DRAWING — PLATE 84

The inking-in process should be carried through in the following sequence:—

① Mark centres of all circles and arcs with point of dividers.
Mark, with a pencil dot, all points of tangency.
Centre lines.
Small circles and arcs (seen and hidden).

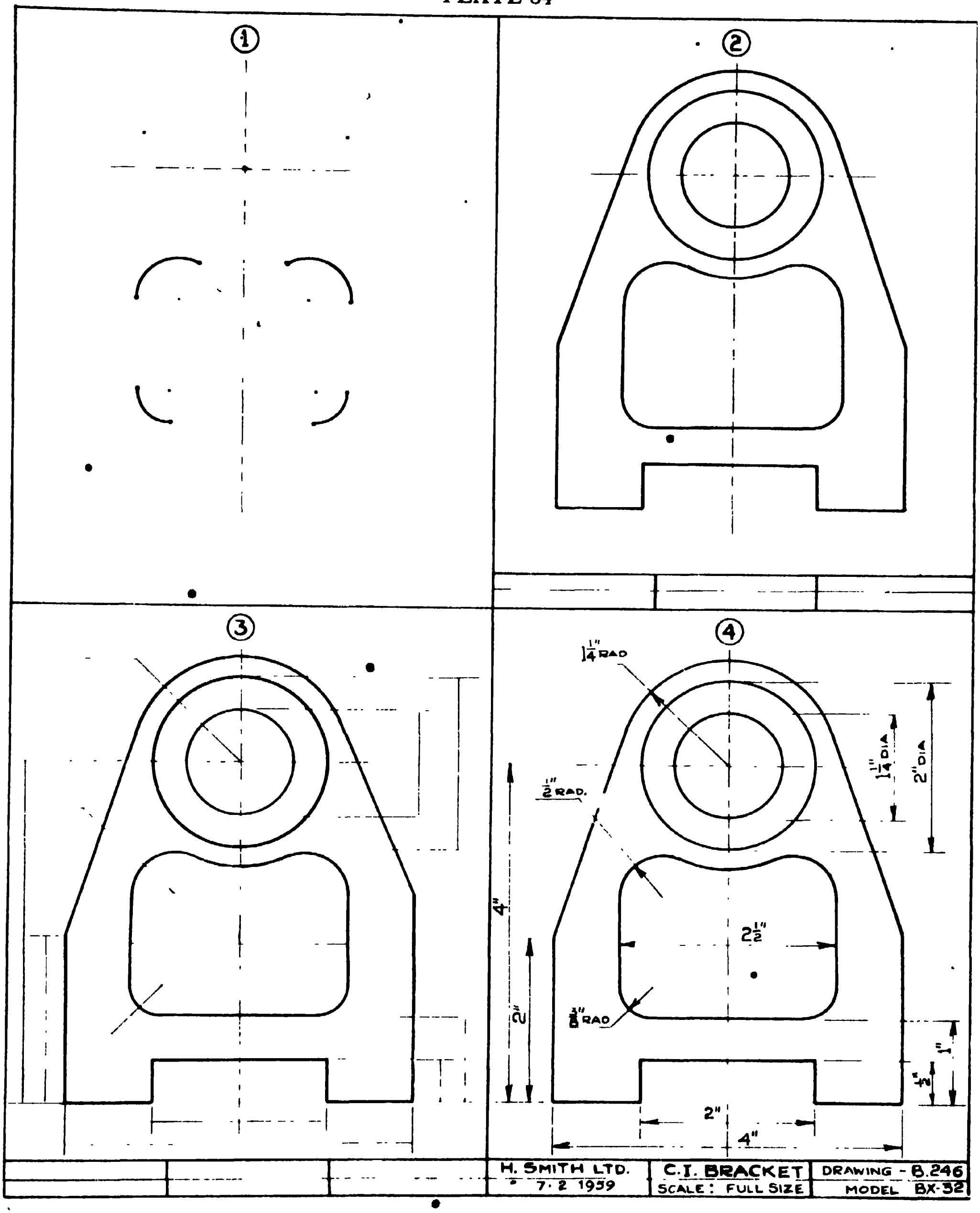
② Large circles and arcs (seen and hidden).
Irregular curves.
Horizontal lines; Vertical lines; Oblique lines (seen and hidden) and in this order.

③ Extension and dimension lines.
Section lines.
Lines in the title table.

④ Dimensions and arrowheads.
Lettering, including notes.
Title and scale.

Ink erasures are difficult to effect on paper; but they may be made satisfactorily by the use of a "*green*" rubber supplied for the purpose. The blade of a knife, or hard ink eraser, should never be tried, as they are sure to damage the surface of the paper. The ink must be absolutely dry before attempting an erasure, and rubbing must be done gently in the direction of the line. Impatience will produce an untidy erasure.

Finally, the drawing should be cleaned up with a soft rubber to remove dirt and pencil lines.


1
2
3
4
1¼" RAD
½" RAD.
1¼" DIA
2" DIA
4"
2½"
2"
⅜" RAD
1"
½"
2"
4"
H. SMITH LTD.
7· 2 1959
C.I. BRACKET
SCALE: FULL SIZE
DRAWING - B.246
MODEL BX-32

TRACING ON CLOTH

The drawing to be traced is generally left in pencil, but complete with dimensions, notes and title. For temporary work, tracings are made on tracing paper; but for permanent records and duplicating purposes the work is done on linen cloth. This is the type of work given to apprentices during their early training in an architect's or engineer's drawing office.

Tracing Cloth: Cloth with a bluish tint is preferable to the white variety, which tends to discolour with age. The most important property of the cloth is transparency. A quality known as "*seconds*" is good enough for school work, and if purchased in a roll the cloth may be cut up economically as required.

Fixing Tracing Cloth: The drawing is "*lined up*" on the board with the tee square and fixed securely in position. The required amount of cloth is cut from the roll, allowing $\frac{1}{2}''$ margin all round the drawing. The cloth has two surfaces, glossy and dull. The correct working surface is the glossy one, and is placed uppermost over the drawing. The cloth should be stretched flat by drawing the palm of the hand over it while the pins are being inserted.

Frequently, tracings and drawings are made on the dull side, as it takes a pencil line and gives a serviceable print thus saving time. It is much better to use ink on the glossy side, which gives a neater, cleaner and altogether better tracing. The drawing ink does not flow easily on the glossy surface, so that it is prepared by dusting with French chalk or pounce. The powder is rubbed into the surface with the finger tips and the surplus removed with a soft cloth.

Order of Tracing Lines: The sequence is the same as that given for inking-in lines on paper (page 226) and the conventional variations in thickness are maintained. The lines on the tracing should be correspondingly slightly thicker to ensure that the drawing will print clearly when copies ("prints") are taken from it. Commence tracing from the top of the drawing, and work from left to right. This allows the ink to dry before the instruments are again placed over the ink work. By glancing sideways across the tracing, one must be continually on the lookout for wet lines. On completion, the tracing should be carefully checked with the drawing to ensure that everything has been traced. Water and moisture damage the tracing cloth permanently.

Erasures on Tracing Cloth: The utmost care must be taken to avoid the necessity for making erasures. An ink line may be obliterated by using a special fluid for the purpose. It may also be removed by rubbing gently with a piece of clean white blotting paper moistened in pure colourless spirits of wine or with a finely graded ink eraser. It is easier to effect a correction on the glossy side of the cloth.

Colouring of Ink Drawings and Cloth Tracings: Engineering drawings and tracings are seldom coloured; but in architectural and building work colour is frequently used, especially when plans are required for official purposes. The choice of the colour to be applied should conform to the conventional colour for the material shown on the drawing. The colour is applied to drawing paper as a light flat wash; but it is applied thickly to the dull side of tracing cloth, as this surface "*takes*" the colour easily. The heavy colour shows up as a light flat wash when viewed from the glossy side.

DUPLICATION OF TECHNICAL DRAWINGS — PLATE 85

Much work is expended on the preparation of drawings and tracings, and it is usual that they should be retained in good condition. Hence, some means is necessary for procuring "*prints*" quickly, and at low cost, for use by others who require them for practical purposes. Prints are made on the same principle as that used in photography, where a celluloid film is placed in contact with sensitised paper and exposed to light. The paper is developed and fixed and any number of copies can be made from the same film. In drawing offices, this work is done on a printing machine specially designed for the purpose. It consists of a hollow vertical cylindrical glass drum on which the tracing (serving the purpose of the film), sensitised paper, and a felt cover are wrapped and securely clamped to the drum. A uniform source of bright light is provided by an electric lamp. The light is lowered for a minute or two into the inside of the drum by a clockwork mechanism which controls the exposure of the light. The sensitised paper is then developed.

Two kinds of print can be produced, Plate 85, viz.,

(1) **BLUE PRINT** which shows the lines of the drawing in white on a dark blue ground.

(2) **OZALID PRINT** which shows the lines of the drawing in black (or red) on a white ground.

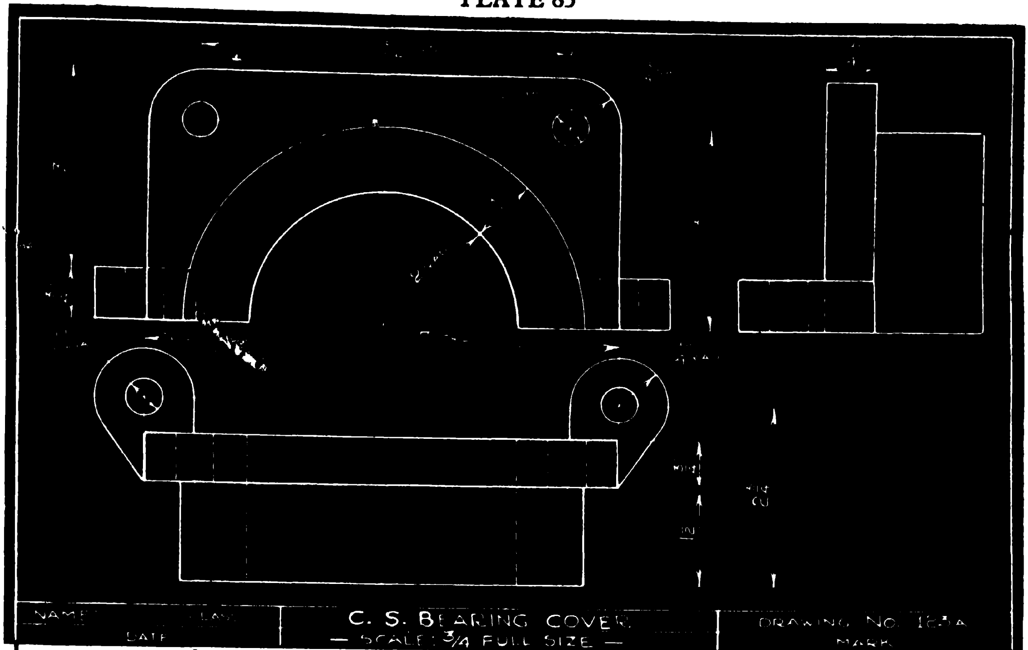
BLUE PRINT: Although this type of print is still used, it has been superseded to a large extent by the Ozalid print. A blue print does not permit of showing alterations and, of course, it cannot be coloured. It is possible to bleach the blue background and alterations would be made in red ink.

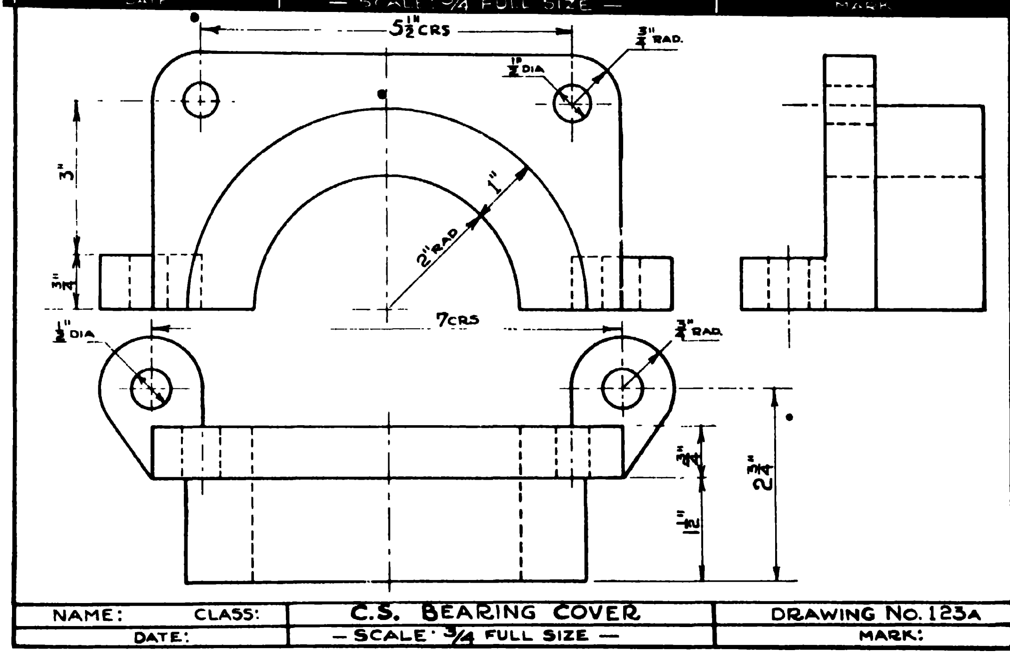
OZALID PRINT: The white ground is a decided advantage. Alterations can be made, or added, and the print can be coloured. A special fluid is available for erasing the black line.

The storage of tracings is a problem in large drawing offices. Use is made of the small camera which photographs the drawing on micro-film about $1\frac{3}{8}'' \times 1''$. Storage capacity is considerably reduced, and the film can be readily enlarged and printed to the original size of the drawing.

Another method of "*reproducing*" the information contained on a drawing is by electronic methods whereby all the information is recorded on a magnetic tape. This method is interesting and is described in detail later in this chapter under the heading of Coordinate Drawing.

PLATE 85


NAME
DATE
C. S. BEARING COVER
— SCALE ¾ FULL SIZE —
MARK


5½" CRS
¾" RAD.
½" DIA
3"
¾"
1"
2" RAD
7 CRS
½" DIA
¾" RAD.
¾"
2¾"
1½"
NAME:
CLASS:
C.S. BEARING COVER
DRAWING No. 123A
DATE:
— SCALE ¾ FULL SIZE —
MARK:

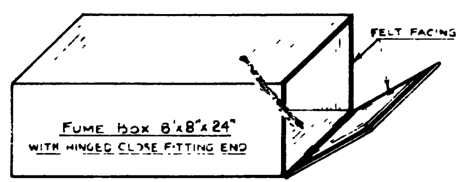
INKING-IN AND PRINTING IN THE CLASSROOM — PLATE 86

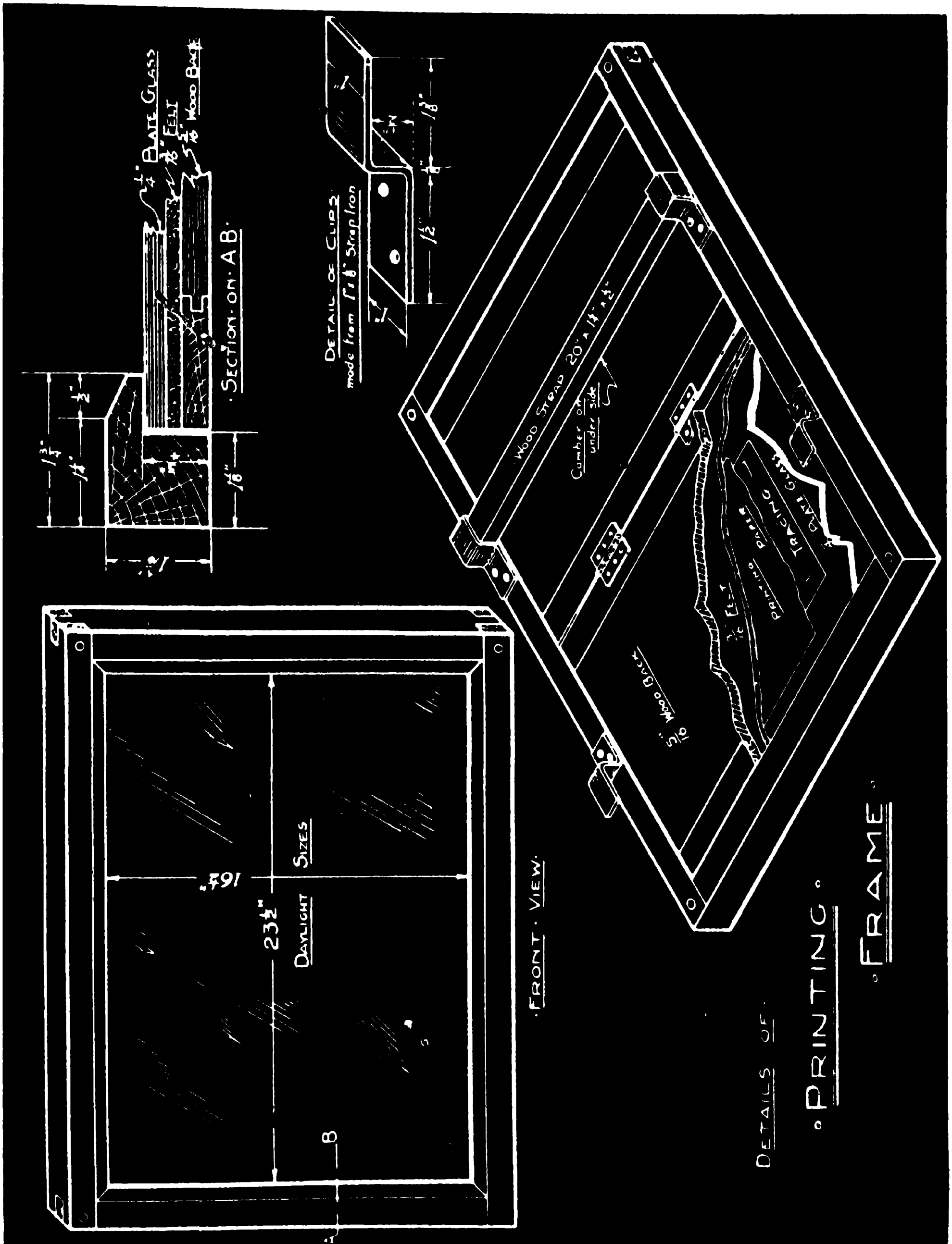
This is considered to be a desirable part of Technical Drawing and the pupil should be given the opportunity of reproducing one or two of his drawings. The process demands skill, accuracy and care from him. Expensive materials and equipment are not required.

Plate 86 shows particulars of a printing frame suitable for taking blue and ozalid prints. Two or three frames could be made as projects in the workshop and prove very useful for taking prints for other purposes.

Printing Procedure: Printing paper is purchased in a roll, 10 yds × 30″ wide, to be opened and cut in a fairly dark light. Once the roll has been opened it tends to deteriorate.

1. Open the frame (if tracing is small, only one half need be hinged back), remove felt, make sure glass is clean and free from dust.
2. Place tracing, face downwards, against the glass, cover with the printing paper, sensitised surface against the tracing, and cover carefully with the felt cloth. Close the frame.
3. Examine from the front to ensure everything is in position, free from creases and folds.
4. Expose to the direct rays of the sun for from 30 seconds (in strong light with "rapid" printing paper) to 3 or 4 minutes (with "slow" paper). The over-lapping edges of the blue printing paper will change from its yellowish-green colour to a greyish-copper during the exposure. Little change in colour appears on the edge of ozalid paper.
5. **Blue Print Development:** When the paper has been sufficiently exposed, it is placed flat in a sink (or bath) and covered with water. After ten minutes, it will be developed, showing white lines on a blue ground. Allow to drip and pin up to dry. The water will turn a greenish colour during washing of the prints and should be changed frequently.
6. **Ozalid Development**: This is a dry process and a fume box is necessary. It can be made of thin wood in the shape of a hollow square prism with one end hinged. A shallow dish containing about an egg-cupful of strong ammonia is placed in the bottom. The exposed print is rolled, with the sensitive surface outside, and placed inside the box for ten minutes. The lines will show up black (or red depending upon the type of printing paper) on a white ground. No washing is required.




DETAILS OF
PRINTING
FRAME
FRONT VIEW
23½"
16¾"
DAYLIGHT SIZES
B
SECTION ON AB
¼" PLATE GLASS
⅛" FELT
5/16" WOOD BACK
1¾"
1¼"
½"
1⅛"
DETAIL OF CLIPS
made from 1" x ⅛" Strap Iron
1½"
WOOD STRAP 20" x 1¼" x ½"
Camber on under side
5/16" WOOD BACK
⅛" FELT
PRINTING PAPER
TRACING
PLATE GLASS

CO-ORDINATE DRAWING

The conventional method of dimensioning a drawing is replaced by a system of co-ordinate reference points on each view. This enables the information contained on the drawing to be arranged in a form (Co-ordinate Table) whereby it can be transformed for reproduction on a magnetic tape similar to that used for speech recording. In fact, the "language" of Technical Drawing is actually reproduced, not merely as a print, but capable of direct control of a machine tool during manufacturing processes.

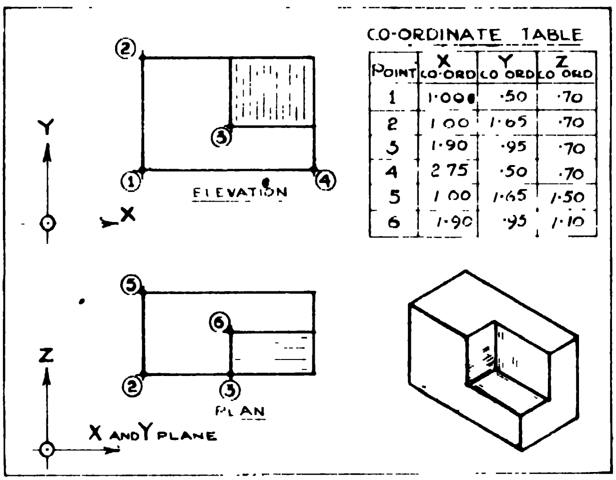
As the pupil proceeds with his study of mathematics, he will become acquainted with a branch of the subject known as Analytical Geometry, which was introduced by Descartes (1596-1650). The principle is that of a co-ordinate system for plotting points similar to that used in drawing graphs.

As applied to Technical Drawing, there are the usual **X** and **Y** axes, or datum lines, from which a point can be plotted by two dimensions on a plane surface. In addition, a **Z** axis is introduced, as a datum line, to provide for the third dimension. If the **X** and **Y** axes are used as datum lines for plotting points for length and height in an elevation, then the **Z** axis can be used for showing breadth, or thickness, in the corresponding plan.

Fig. 303 shows a simple example of this type of drawing along with its Table of Co-ordinate Points.

Height is measured upwards on the **Y** axis, so that the total height is represented by the difference between the points **2** and **1**. Refer to the Table for the ordinates at these points (1.65″ – .50″) gives the height as 1.15″.

Length is measured along the **X** axis and represented by the difference between **4** and **1** (2.75″ – 1″) is 1.75″.



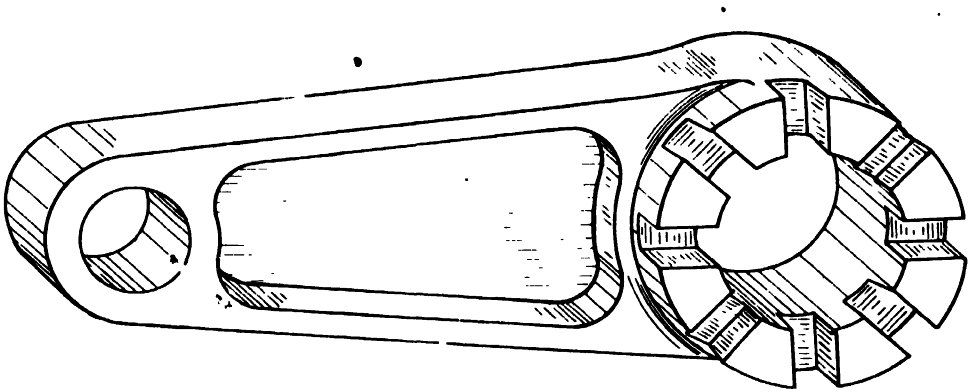
CO-ORDINATE TABLE

POINT	X CO-ORD	Y CO ORD	Z CO ORD
1	1·00	·50	·70
2	1 00	1·65	·70
3	1·90	·95	·70
4	2 75	·50	·70
5	1 00	1·65	1·50
6	1·90	·95	1·10

Fig. 303

Breadth (or Thickness) is measured on the **Z** axis and is represented by the difference between **5** and **2** i.e. (1.50″ – .70″) is .80″.

If you imagine that the Z axis is folded upwards and at right angles to the X and Y axes, then the co-ordinate points become points on the solid, viewed by First Angle Projection.

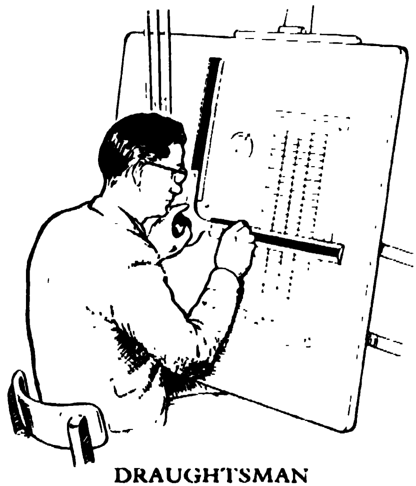


CONTROL LEVER

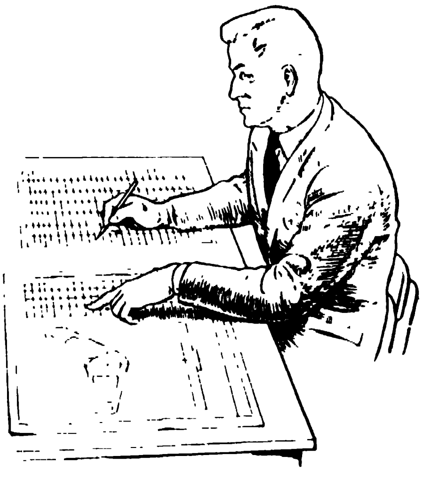
PREPARATION OF A CO-ORDINATE DRAWING — PLATE 87 (Page 237)

The sketch of a control lever is shown above and Fig. 304 (Plate 87) shows the corresponding co-ordinate drawing with the various important "points of change", indicated by dots, numbered consecutively.

After fixing the X, Y and Z axes, or datum lines, in the left hand corner; the draughtsman makes use of them to determine the co-ordinates of all "points of change" in direction of lines, together with the centres of circles, radii, tangency points, etc. The centre lines are used for dimensional purposes.



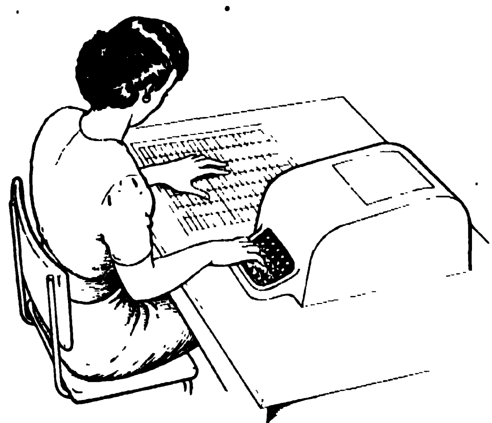
DRAUGHTSMAN



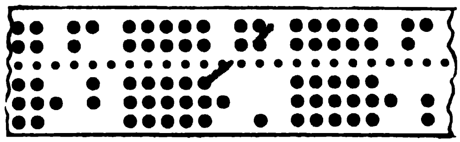
PLANNING ENGINEER

The co-ordinate drawing, with its relative Table, is submitted to the Planning Engineer for consideration of the machining processes required in the course of manufacture. The work is now said to have been "*programmed*" and the **Planning Sheet** is complete. This Sheet now contains information, not only regarding dimensions, but also instructions to the machine as to how the "tooling" will be carried through.

The next step is the encoding of the information contained in the Planning Sheet, and for this purpose a **Teleprinter** is used. This machine is similar to a typewriter; but on depressing the keys a pattern of holes is punched on a strip of paper.

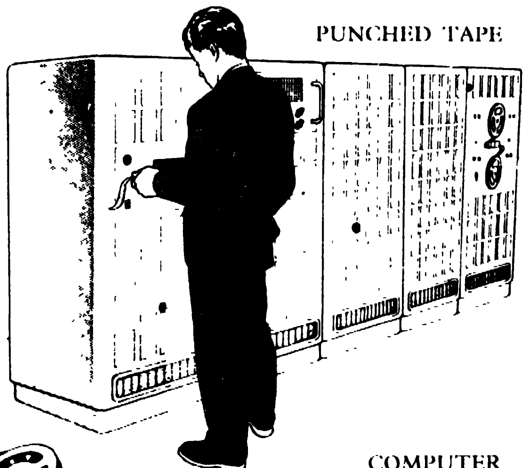


TELEPRINTER



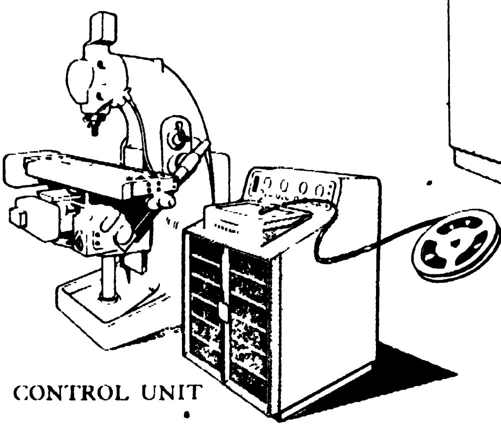
PUNCHED TAPE

The punched tape is passed into a **Computer** which *"records"* all the information, contained on the punched paper strip, on a thin magnetic tape (wound on a reel) similar to that used for recording speech on a tape recorder.



COMPUTER

The magnetic tape is then used in the **Control Unit** which is placed alongside the machine tool. The tape sends an electrical signal to operate the required motor on the machine so that it will do exactly as required.



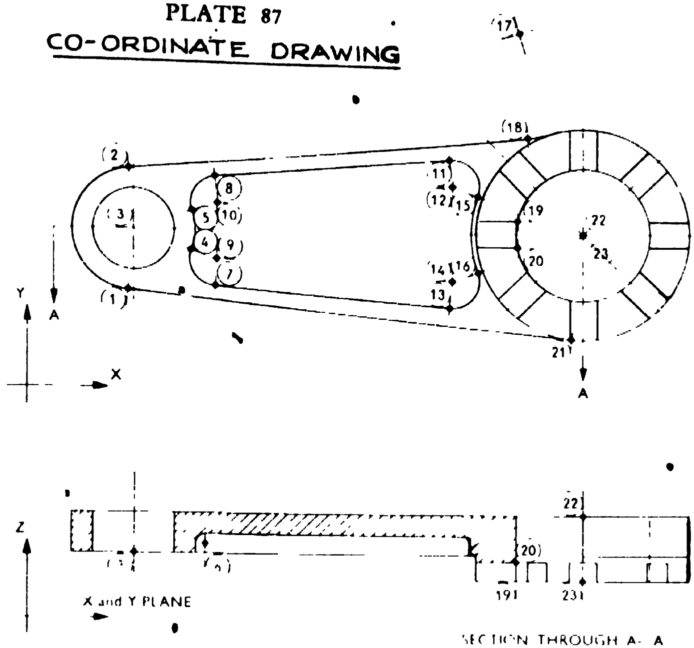
CONTROL UNIT

Compare Fig. 305, which shows the control lever drawn and dimensioned in the conventional manner, with Fig. 304, prepared by Co-ordinate Drawing. The outline is more clearly defined by the co-ordinate system, due to the absence of dimension lines, arrowheads, sizes and any explanatory notes.

The pupil will have a better understanding of co-ordinate drawing if he draws the control lever (Fig. 304) from the Co-ordinate Table (approx. second decimal place) to a scale of twice full size, either on squared or drawing paper.

PLATE 87

CO-ORDINATE DRAWING



CO-ORDINATE TABLE

Change Points	X CO ORD	Y CO ORD	Z CO-ORD
1	0 942	0 941	1 000
2	0 955	2 061	1 000
3	1 000	1 500	0 625
4	1 534	1 323	0 625
5	1 538	1 665	0 625
6	1 656	1 500	0 719
7	1 749	0 995	0 625
8	1 760	1 988	0 625
9	1 771	1 244	0 813
10	1 777	1 739	0 813
11	3 979	2 134	0 625
12	3 995	1 884	0 813
13	3 997	0 795	0 625
14	4 019	1 044	0 813
15	4 234	1 811	0 625
16	4 254	1 131	0 625
17	4 485	3 348	—
18	4 565	2 351	1 000
19	4 638	1 625	0 563
20	4 638	1 375	0 563
21	5 147	0 505	1 000
22	5 250	1 500	1 000
23	5 250	1 500	0 375

Fig. 304

CONVENTIONAL DRAWING

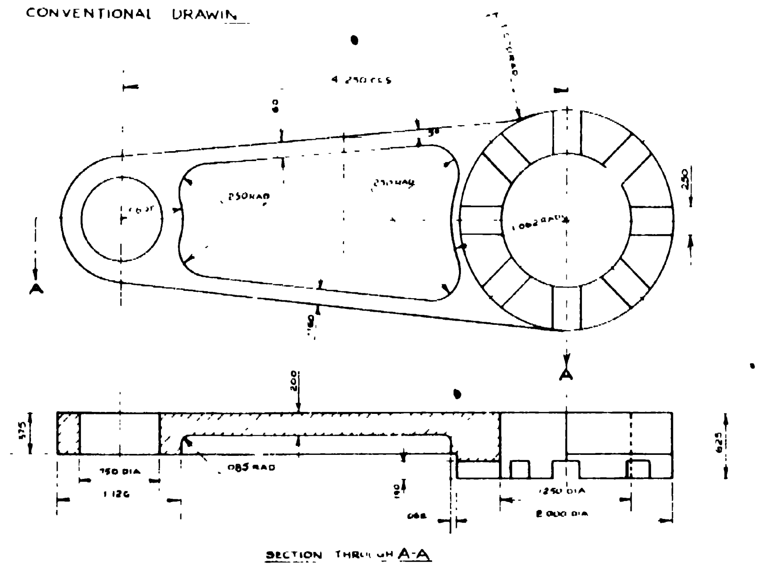


Fig. 305

DIMENSIONS IN INCHES

TRAFFIC SIGNALS

The signals are operated according to traffic requirements, e.g. (a) Automatically, based on time intervals, (b) By passing vehicles as they approach the junction, (c) By hand to suit special conditions.

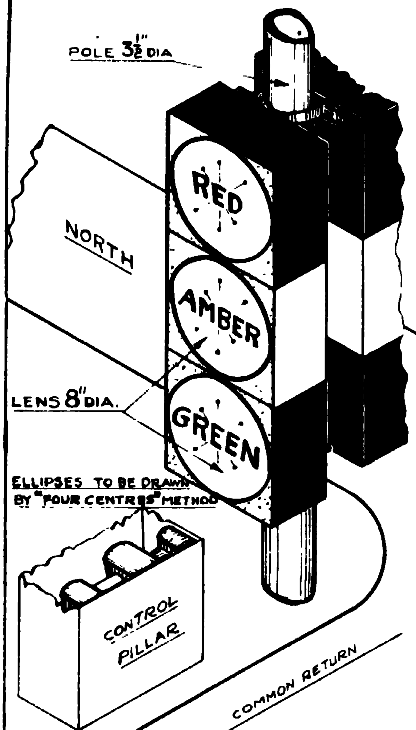
Normal sequence of signals:—

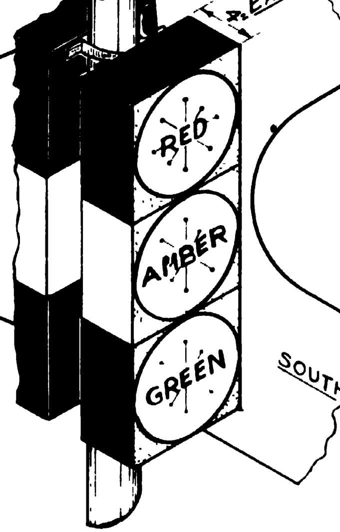
RED—Stop, and wait at the "Stop Line" on the road.

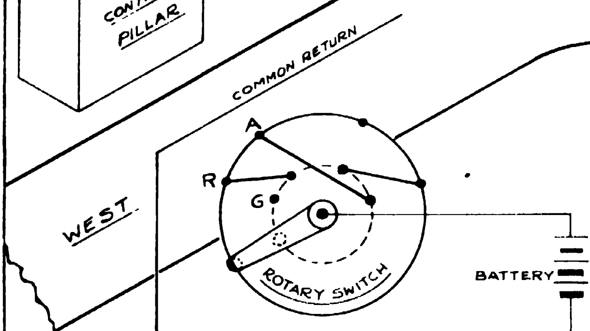
RED AND AMBER TOGETHER—Prepare to start when green is shown.

GREEN—Proceed subject to safety of others.

AMBER ALONE—Stop at the "Stop Line" unless when the amber first appears the vehicle is so close to the crossing that to pull up would be dangerous.





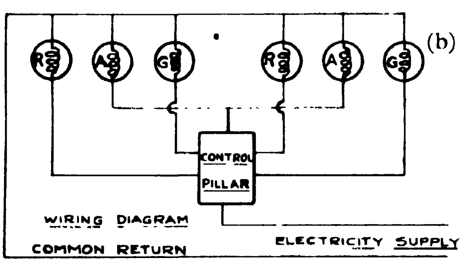


EXERCISE — Use 22" × 15" paper

(a) Draw, to a scale of one quarter full size, the isometric view of the Signal Lights and crossing.

(b) The wiring diagram of connections. Assume the lights could be controlled by a simple rotary switch, draw the wiring to each set of lights to give normal sequence and note that the "return" wire from each light joins in one "common return" wire.

It would be an interesting project to make a model of the signals and rotary switch using 6 or 12 volt. battery and lamps.



EXERCISE 70 — Use 22″×11″ paper

The handle of a tenon saw for wood is shown.
Draw, to a scale of full size, insert all dimensions and mark, with a heavy dot, all points of tangency.

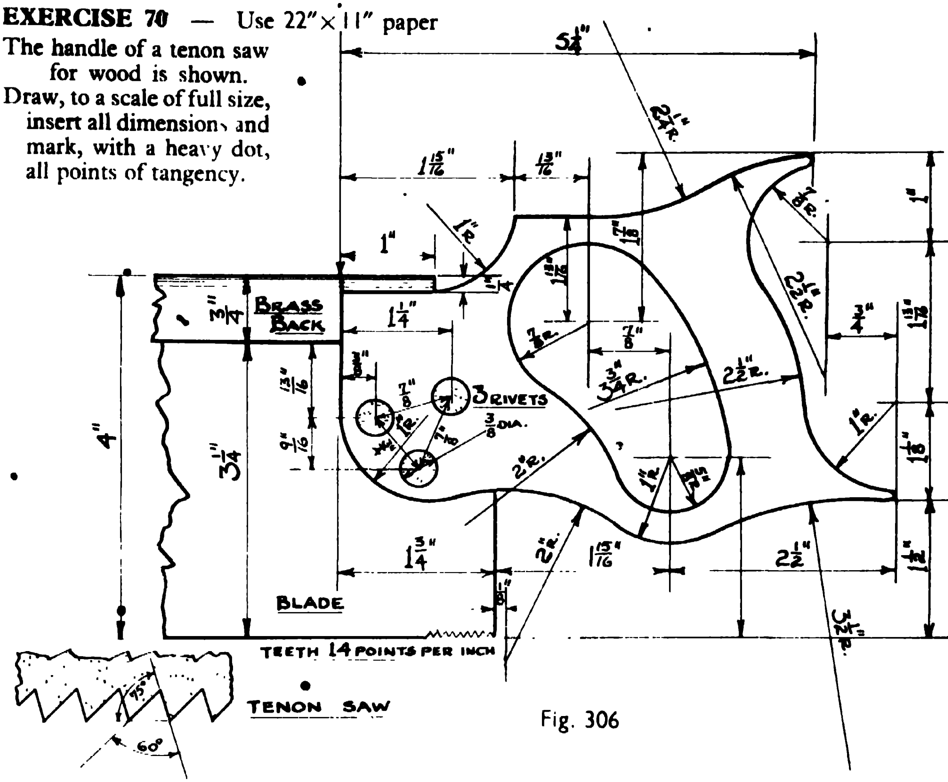
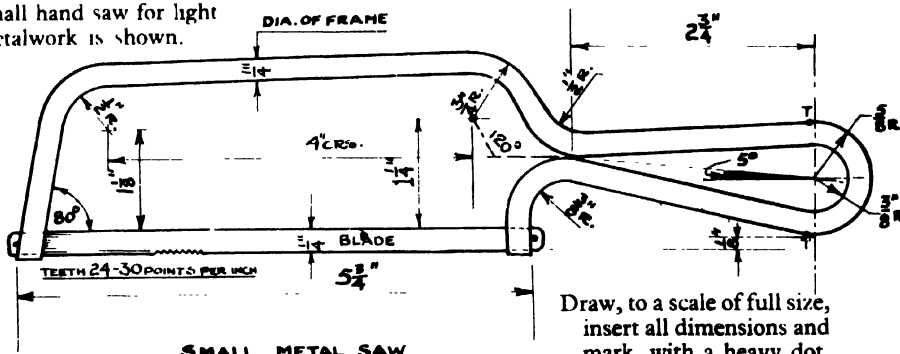


Fig. 306

A small hand saw for light metalwork is shown.



Draw, to a scale of full size, insert all dimensions and mark, with a heavy dot, all points of tangency.

Fig. 307

EXERCISE 71 — Use 22″ × 15″ paper — PLATE 90

The component parts are shown of a spherical-headed swivel pin joint carrying a circular table and arranged for clamping to a bench.

Draw the complete assembly, to a scale of full size, showing:

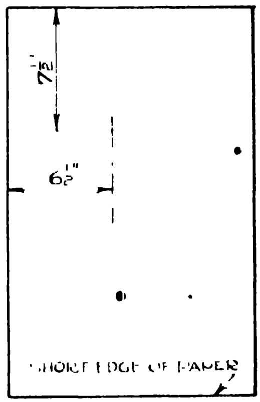
(a) The elevation.

(b) The plan.

Mark all points of tangency with a heavy dot.

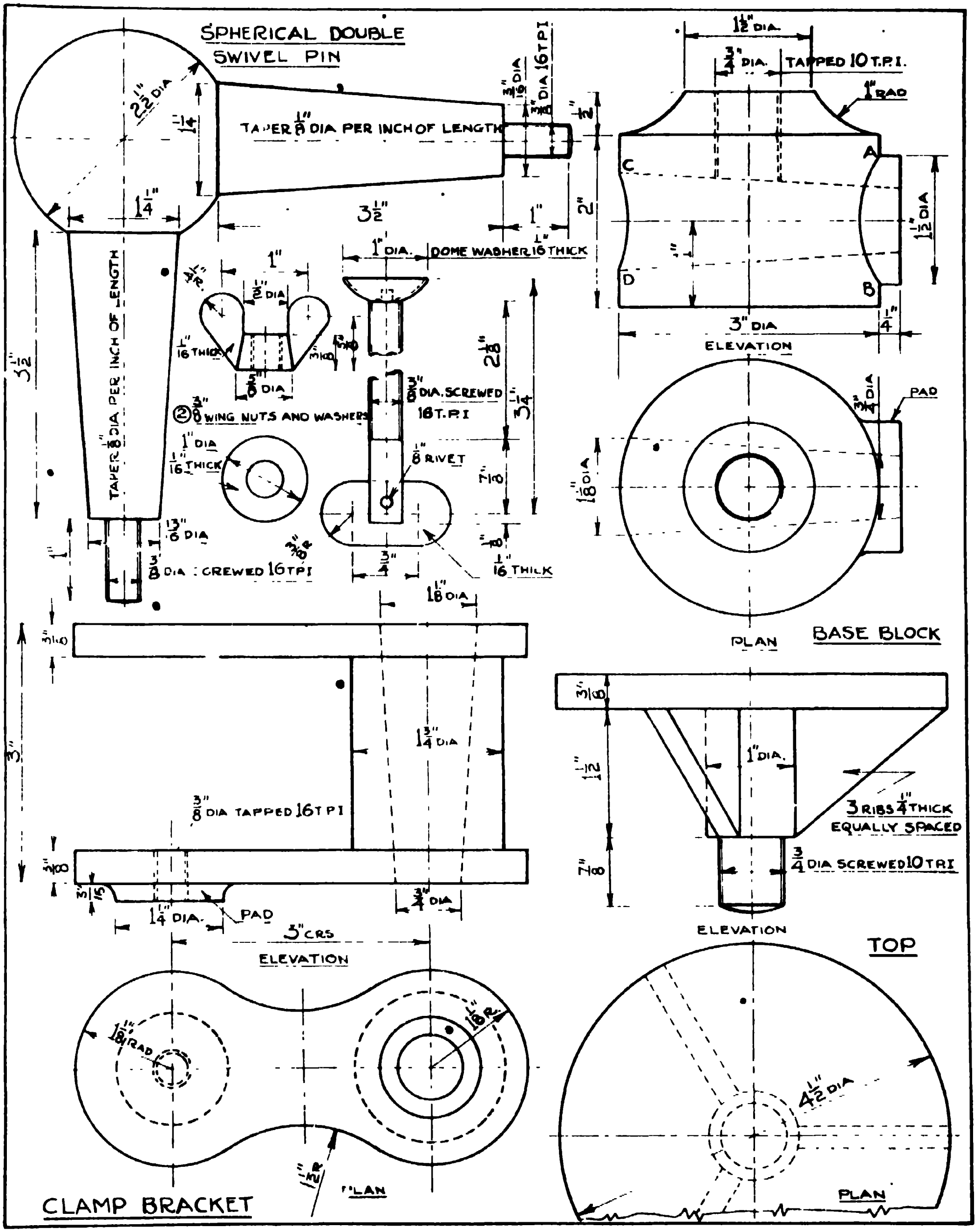
Show the construction for obtaining the curve **A-B** but curve **C-D** may be drawn free-hand after fixing the limiting points.

The dimensions given here indicate the positions, on the paper, of the centre lines through the sphere in elevation.



NOTE: The positions of the clamp bracket and base block are determined from the taper on the spindle in the sockets.

PLATE 90


SPHERICAL DOUBLE SWIVEL PIN
TAPER 1/8" DIA PER INCH OF LENGTH
2 1/2" DIA
1 1/4"
3 1/2"
1"
3/8 DIA SCREWED 16TPI
13/16 DIA
(2) 3/8" WING NUTS AND WASHERS
DOME WASHER 1/16 THICK
1" DIA
3/8 DIA. SCREWED 16T.P.I
1/8 RIVET
1/16 THICK
BASE BLOCK
1 1/2" DIA
3/4" DIA
TAPPED 10 T.P.I.
1" RAD
3" DIA
ELEVATION
PLAN
PAD
1 1/8" DIA
1 3/4" DIA
3/8" DIA TAPPED 16T PI
1 1/4" DIA.
3/4" DIA
5" CRS
ELEVATION
1 1/8" RAD
1 1/2" R
PLAN
CLAMP BRACKET
TOP
1" DIA.
3 RIBS 1/4" THICK EQUALLY SPACED
3/4 DIA SCREWED 10 TPI
ELEVATION
4 1/2" DIA
PLAN

EXERCISE 72 — Use 22″ × 15″ paper — PLATE 91

The component parts are shown of a plummer block bearing suitable for a 4″ diam. shaft.

Draw the complete assembly, to a scale of half full size, showing:

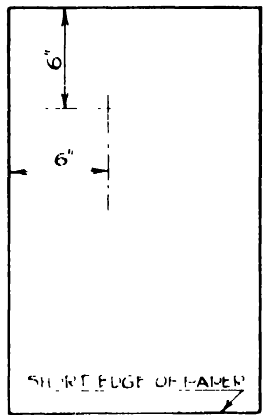
(a) The elevation.

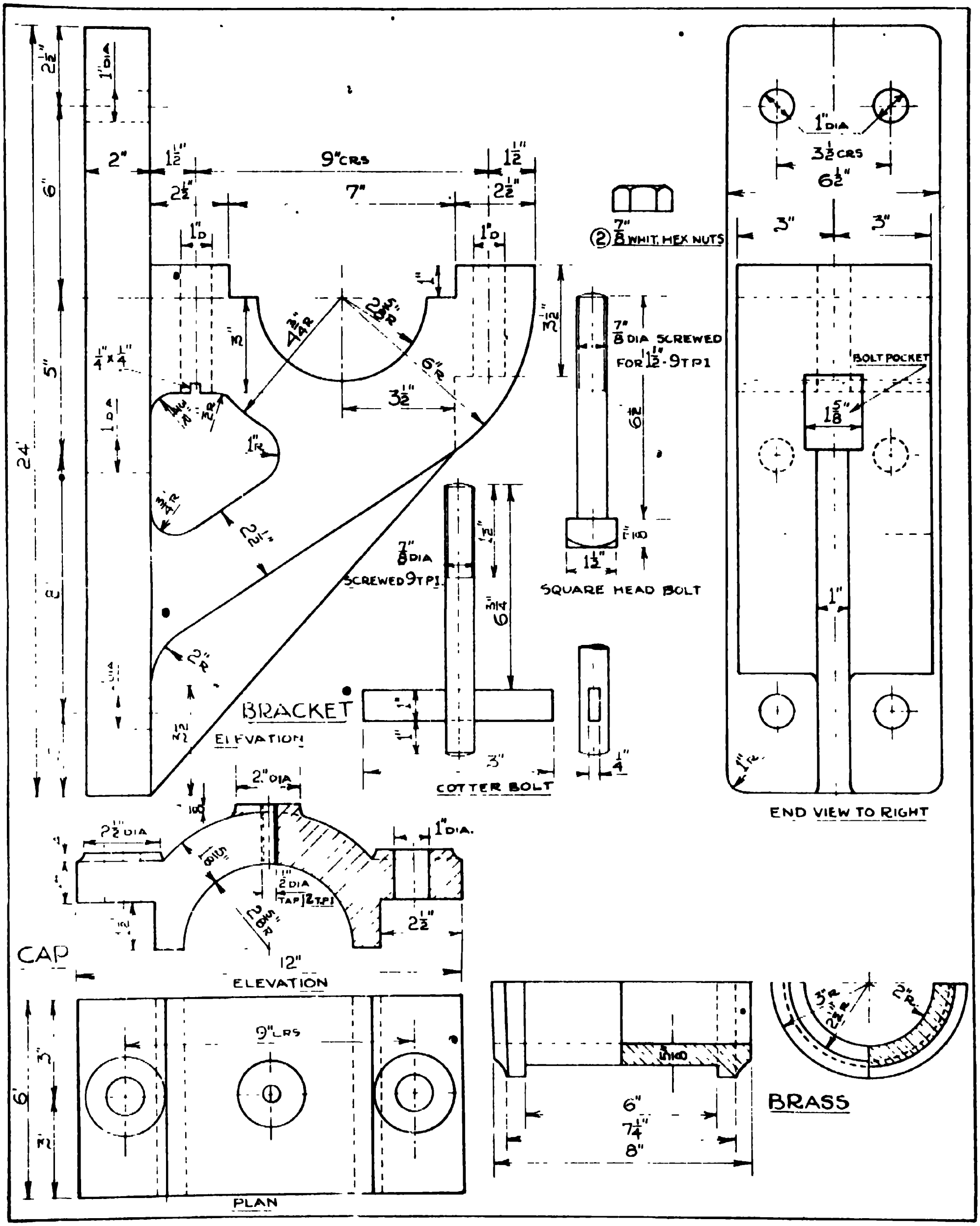
(b) The end view to the right.

(c) The plan with the cap, brasses and bolts removed.

Mark all the points of tangency with a heavy dot.

The dimensions given here indicate the positions of centre lines on the paper.




BRACKET
ELEVATION
9" CRS
7"
2"
$1\frac{1}{2}$"
$2\frac{1}{2}$"
24"
$\frac{1}{4}$" x $\frac{1}{4}$"
6" R
2" R
$3\frac{1}{2}$"
(2) $\frac{7}{8}$ WHIT. HEX NUTS
$\frac{7}{8}$ DIA SCREWED FOR $1\frac{1}{2}$ - 9 TPI
SQUARE HEAD BOLT
$\frac{7}{8}$ DIA SCREWED 9 TPI
COTTER BOLT
1" DIA
$3\frac{1}{2}$ CRS
$6\frac{1}{2}$"
3"
BOLT POCKET
$1\frac{5}{8}$"
1"
END VIEW TO RIGHT
CAP
2" DIA
$2\frac{1}{2}$" DIA
1" DIA.
$\frac{1}{2}$" DIA TAP 12 TPI
12"
ELEVATION
9" CRS
6"
PLAN
6"
$7\frac{1}{4}$"
8"
BRASS

EXERCISE 73 — Use 22″ × 15″ paper — PLATE 92

The component parts are shown of a tool holder for a shaping machine.

Draw, to a scale of full size, the following views:

SECTION A in first angle projection:

(a) The given elevation of the back plate.

(b) The plan.

(c) Alongside the above, draw the given elevation of the tool post holder and add a sectional plan on **A-B.**

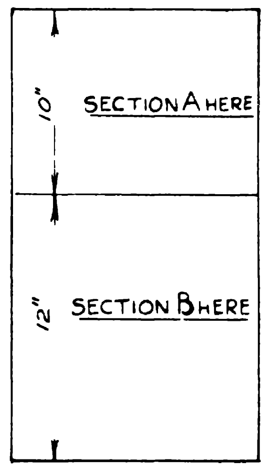
(d) Down the right hand side, draw the given details of the tool post, fixing screw, bevelled washer and grub screw.

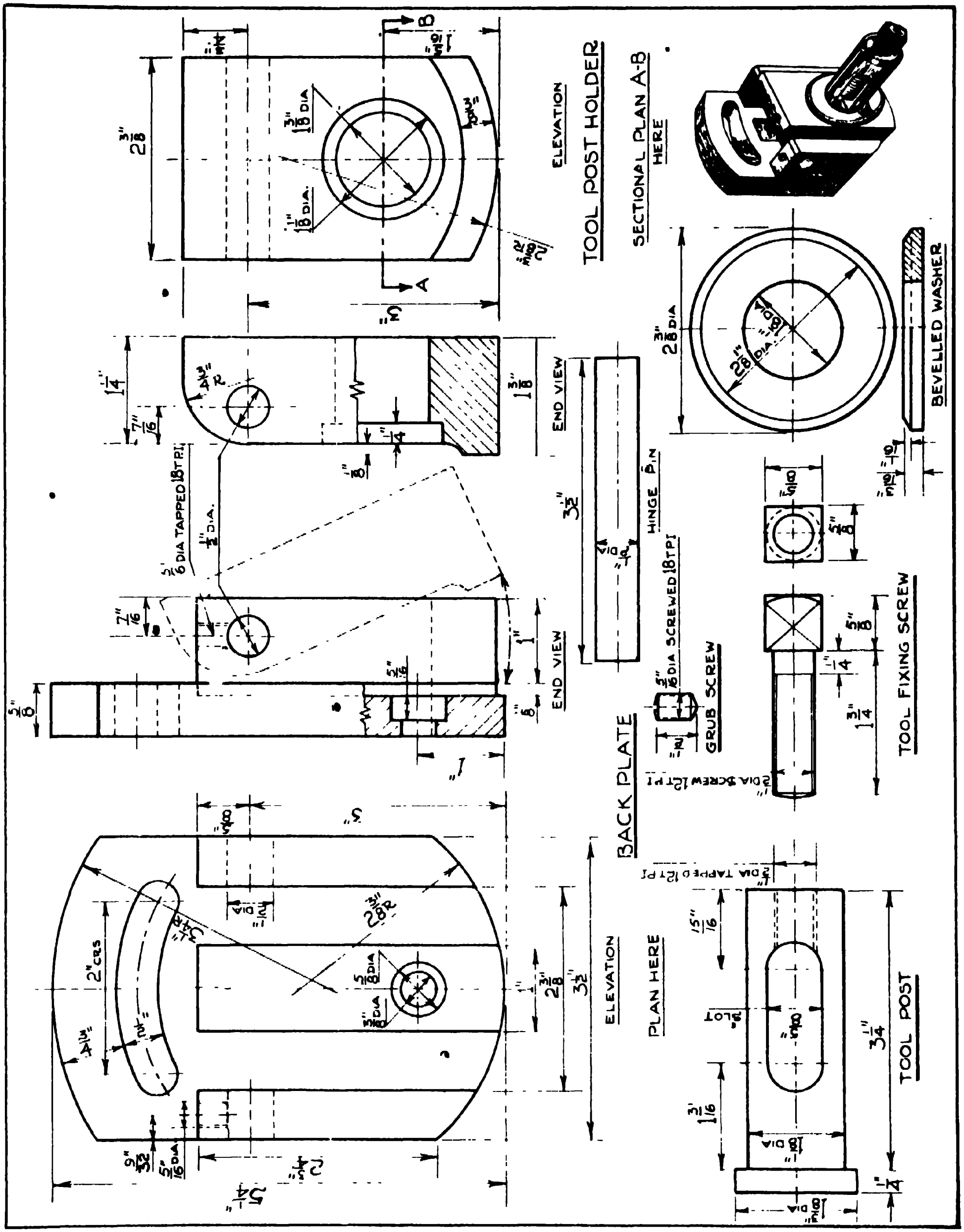
SECTION B in third angle projection:

(a) The plan of the complete assembly with the back plate in the Horizontal Plane, centre line parallel to the Vertical Plane, and the tool post on the right.

(b) The longitudinal sectional elevation through the centre line in the plan.

(c) The two end views in full.




TOOL POST HOLDER
ELEVATION
SECTIONAL PLAN A-B HERE
END VIEW
END VIEW
BACK PLATE
HINGE PIN
GRUB SCREW
TOOL FIXING SCREW
BEVELLED WASHER
ELEVATION
PLAN HERE
TOOL POST

EXERCISE 74 — PLATE 93

1. The perimeter of an isosceles triangle is $6\frac{1}{2}''$. If the base is $1\frac{1}{2}''$, find (*a*) the area of the triangle, (*b*) the altitude of the triangle.

2. An observer sees an airship approaching him at a uniform height of 1000 feet. When first observed, the angle of elevation is 15°. After a period of 30 seconds, a second observation is taken, when the angle of elevation is found to be 35°. Record this graphically, to a scale of 1″ to 500 feet, and measure:

(a) The distance the airship has travelled between the taking of the two observations.

(b) Its speed in miles per hour.

3. The following members form part of the framework of a kite: 2 pieces each 16″ long, 2 pieces each 30″ long, 1 piece, as a horizontal stay, 24″ long.

Find: (a) The length of the sixth member required as a vertical stay.

(b) The area of the material, in square inches, covering one surface of the kite.

4. Find the actual area of metal on the underside of a 2″ hexagon nut.

5. Assuming there is no waste, find how many sheets of tin, each 6′ × 2′ 6″, will be required to make 1000 circular cocoa tins, each 3″ diam. and 4″ high.

6. Find the area swept out by the minute hand of a clock in 10 minutes, if the clock face is 8″ diameter.

7. The cross section of a tunnel forms the major segment of a circle, whose diameter is 16′. The track is a chord of this circle and subtends an angle of 90° at the centre. Draw, to a scale of 1″ to 4′, and measure:

(a) The length of the arc forming the tunnel.

(b) The width of the track.

(c) The vertical height to the crown of the tunnel.

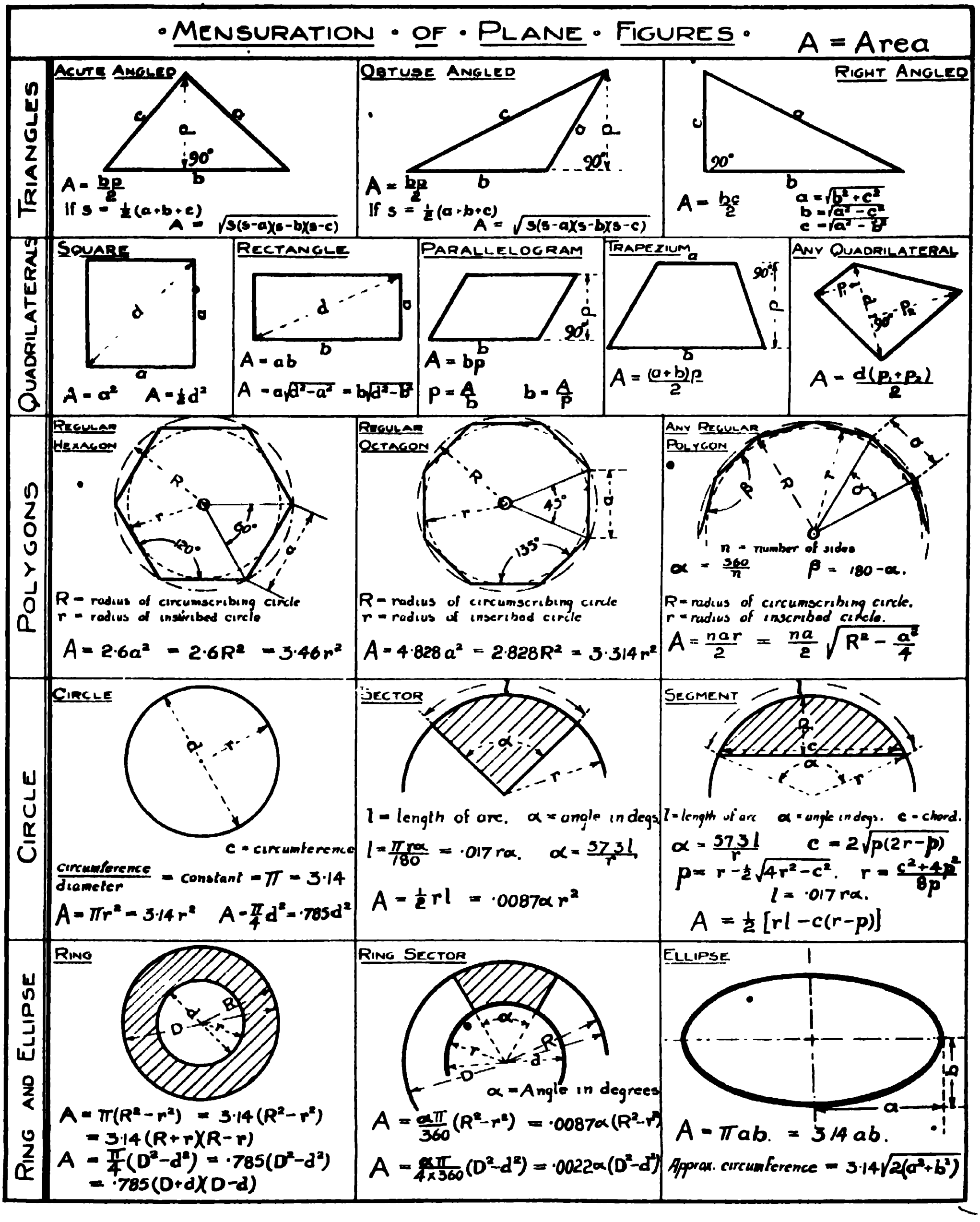
Check your answer numerically and calculate, in square feet, the area of the cross section.

8. Find the area of cross section of a hollow steel shaft, $1\frac{1}{2}''$ thick, and internal diameter 8″.

9. Find the weight of a boiler plate, 10′ 6″ × 4′ 9″ × $\frac{3}{4}''$ thick. ($\frac{3}{4}''$ plate weighs 30 lb. per square foot).

If an elliptical inspection hole, 18″ × 12″, is to be cut in the plate, how much lighter will it become?

PLATE 93


• MENSURATION • OF • PLANE • FIGURES •
A = Area
TRIANGLES
ACUTE ANGLED
$A = \frac{bp}{2}$
If $s = \frac{1}{2}(a+b+c)$
$A = \sqrt{s(s-a)(s-b)(s-c)}$
OBTUSE ANGLED
$A = \frac{bp}{2}$
If $s = \frac{1}{2}(a+b+c)$
$A = \sqrt{s(s-a)(s-b)(s-c)}$
RIGHT ANGLED
$A = \frac{bc}{2}$
$a = \sqrt{b^2+c^2}$
$b = \sqrt{a^2-c^2}$
$c = \sqrt{a^2-b^2}$
QUADRILATERALS
SQUARE
$A = a^2$ $A = \frac{1}{2}d^2$
RECTANGLE
$A = ab$
$A = a\sqrt{d^2-a^2} = b\sqrt{d^2-b^2}$
PARALLELOGRAM
$A = bp$
$p = \frac{A}{b}$ $b = \frac{A}{p}$
TRAPEZIUM
$A = \frac{(a+b)p}{2}$
ANY QUADRILATERAL
$A = \frac{d(p_1+p_2)}{2}$
POLYGONS
REGULAR HEXAGON
R = radius of circumscribing circle
r = radius of inscribed circle
$A = 2{\cdot}6a^2 = 2{\cdot}6R^2 = 3{\cdot}46r^2$
REGULAR OCTAGON
R = radius of circumscribing circle
r = radius of inscribed circle
$A = 4{\cdot}828a^2 = 2{\cdot}828R^2 = 3{\cdot}314r^2$
ANY REGULAR POLYGON
n = number of sides
$\alpha = \frac{360}{n}$ $\beta = 180 - \alpha$.
R = radius of circumscribing circle.
r = radius of inscribed circle.
$A = \frac{nar}{2} = \frac{na}{2}\sqrt{R^2 - \frac{a^2}{4}}$
CIRCLE
CIRCLE
c = circumference
$\frac{\text{circumference}}{\text{diameter}}$ = constant $= \pi = 3{\cdot}14$
$A = \pi r^2 = 3{\cdot}14r^2$ $A = \frac{\pi}{4}d^2 = {\cdot}785d^2$
SECTOR
l = length of arc. α = angle in degs.
$l = \frac{\pi r\alpha}{180} = {\cdot}017r\alpha$. $\alpha = \frac{57{\cdot}3\,l}{r}$
$A = \frac{1}{2}rl = {\cdot}0087\alpha r^2$
SEGMENT
l = length of arc α = angle in degs. c = chord.
$\alpha = \frac{57{\cdot}3\,l}{r}$ $c = 2\sqrt{p(2r-p)}$
$p = r - \frac{1}{2}\sqrt{4r^2-c^2}$. $r = \frac{c^2+4p^2}{8p}$
$l = {\cdot}017r\alpha$.
$A = \frac{1}{2}[rl - c(r-p)]$
RING AND ELLIPSE
RING
$A = \pi(R^2-r^2) = 3{\cdot}14(R^2-r^2)$
$= 3{\cdot}14(R+r)(R-r)$
$A = \frac{\pi}{4}(D^2-d^2) = {\cdot}785(D^2-d^2)$
$= {\cdot}785(D+d)(D-d)$
RING SECTOR
α = Angle in degrees
$A = \frac{\alpha\pi}{360}(R^2-r^2) = {\cdot}0087\alpha(R^2-r^2)$
$A = \frac{\alpha\pi}{4\times360}(D^2-d^2) = {\cdot}0022\alpha(D^2-d^2)$
ELLIPSE
$A = \pi ab = 3{\cdot}14\,ab$.
Approx. circumference $= 3{\cdot}14\sqrt{2(a^2+b^2)}$